DEPARTMENT OF
SCIENTIFIC AND INDUSTRIAL RESEARCH

FOREST PRODUCTS RESEARCH 1954

LONDON: HER MAJESTY'S STATIONERY OFFICE
1955
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DEPARTMENT OF
SCIENTIFIC AND INDUSTRIAL RESEARCH

REPORT OF THE FOREST PRODUCTS RESEARCH BOARD

WITH THE REPORT OF THE DIRECTOR
OF FOREST PRODUCTS RESEARCH
FOR THE YEAR

1954

LONDON: HER MAJESTY'S STATIONERY OFFICE
1955

FOREST PRODUCTS RESEARCH BOARD
1954

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[1] Until 31st March, 1954
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DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH,
Charles House, 5-11 Regent Street,
London, S.W.1.

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REPORT OF THE FOREST PRODUCTS RESEARCH BOARD FOR THE YEAR 1954

To the Lords of the Committee of the Privy Council for Scientific and Industrial Research

MAY IT PLEASE YOUR LORDSHIPS,

WE, the Forest Products Research Board, beg leave to present our report for the year ending 31st December, 1954.

Such changes as have occurred in the national timber situation during the year have not required any significant alteration in the scope and orientation of the work of the Laboratory, and the year's effort has again been devoted to the normal development of the research programme, the routine examination of new timbers, investigations into the industrial processing of wood, and the continuing heavy demands for data and advice. There has been no remission in carrying to industry the results of the Laboratory's work and the fruits of its experience not only through the media of reports, enquiries and lectures, but also through constant personal contact of the Laboratory's staff with members of the wood-using industries.

In addition to the dissemination of information in specific technical fields, education in general timber technology has again been undertaken to the limit of staff available. The annual courses to foresters, both undergraduate and post-graduate, are important because they enable the grower to appreciate the processing and end uses of his crop. The various special courses, such as that arranged for architects concerned with the maintenance of historic churches, are also valuable not only for their limited objective of showing how to deal with the commoner problems of inspection and treatment but also because they increase the number of those who know the Laboratory and turn to it when they encounter difficulties requiring more specialized knowledge and experience. The same is true of all the courses of instruction, whether to the producing or the using side of the industry.

We are gratified to report the Laboratory's advancing reputation as a centre for individual study, especially for students from overseas. During the last five years, almost without intermission, there have been one or more Commonwealth or foreign students on long-term courses. The number of overseas visitors also remains high, and during the current year they came from no fewer than 35 countries.

In pursuit of the policy which we have previously reported, there has been some decrease in emphasis on the testing and assessment of new Colonial timbers, as more of the time of the Laboratory has been taken up with the consignments of various species of home-grown timbers being examined in

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co-operation with the Forestry Commission. Although this arrangement is still in its early stages, interesting and useful information on several of the species has already been gained.

All Sections, in greater or lesser degree, are carrying out some work on more basic projects, but we are still not content with the amount of effort which can be spared from the advisory and routine testing work for these projects. The research staff have not lost the healthy curiosity to go further into those problems which the applied research and the advisory enquiries bring to light, and we wish that they had more ample opportunity to pursue them.

We are pleased to record the continuing close and cordial co-operation between the Laboratory and all those bodies, industrial and official, with which it has common interests. We wish, also, to thank those who, individually, have given their assistance and advice, and especially those who have again so freely made their contribution to the successful year's work of the Laboratory's industrial advisory panels.

The Director's report summarizes the work of the various Sections during the year. We would here wish to draw your Lordships' attention to the following items of particular interest :

TROPICAL TIMBERS

There is an undiminished demand for knowledge about Commonwealth and other tropical timbers, their uses and processing, and the possibility of utilizing them as substitutes for more commonly known ones. The interest of the trade in their material has again been exemplified by numerous enquiries on abnormalities which have been observed during the handling of the timbers. The advisory work on these matters is one of the Laboratory's unspectacular but very important services to industry.

KILN SEASONING

To follow up the fairly satisfactory results obtained in drying Scots pine and some of the lighter hardwoods at elevated temperatures, further experiments have been made to study the behaviour of Douglas fir, oak, balsa and African mahogany under similar conditions. While the Douglas fir behaved satisfactorily both the oak and the balsa suffered very seriously at temperatures above boiling point. The African mahogany which had been dried at about 100°C seasoned rapidly and did not split, but the degree of collapse produced would lead to a conversion loss of 5 to 10 per cent. In practice such loss, together with that of deterioration of the kiln caused by the use of high temperatures, would have to be set against the saving made on the decreased times of drying.

A report has been published on the moisture gradients in wood which has one face in contact with water, as it commonly has in vats and barrels. When a steady state has been reached, the moisture gradient within the wood is not an even one, but is very steep near the wetted face, with a much flatter gradient through the bulk of the material. In samples of wood whose outer surface had been coated with paint, as is often seen with rain-water barrels, the timber attains a moisture content under the paint of over 20 per cent, and is therefore susceptible to attack by wood-rotting fungi.

TIMBER MECHANICS

A very satisfactory year has been completed in Timber Mechanics by the publication of several reports on projects which provide data of importance to those who design in timber. Following the appearance last year of a bulletin on the comparison of three-ply woods of a standard thickness, a second bulletin provides simple equations for calculating strength values for any plywood construction from the data given in the first bulletin. In plywood made from thin veneers the adhesive has a marked effect on the strength properties, and a further series of experiments has been put in hand to determine the influence of various adhesives on the strength properties of such types of plywood.

Another published report of interest is that giving the characteristics of timber joints made with round wire nails. For two-member and three-member joints the relations between the thickness of the members, the number and diameter of the nails, and the stiffness and load-carrying properties are described. Further work includes an investigation into the relationship between density of the timber and strength and stiffness in nailed joints.

A theoretical analysis of the performance of two-species laminated beams has been completed and its validity confirmed by tests. These beams are made up by gluing relatively thin layers of strong timber to a core of lighter species, the strong wood being placed at the regions of greatest stress. Methods have been established for calculating the constituents of the beam for minimum weight or for minimum cost. The report is in preparation.

PLYWOOD RESEARCH

To supplement the long-term durability tests started some ten years ago, a new series of tests has been begun which includes representative types of the adhesives in current use, and new testing techniques have been evolved to lessen the labour of maintaining the tests.

The wider use of laminated members, e.g. in boat keels, often results in their being made up under conditions where close control may not be possible. To determine the tolerance permissible during manufacture, experiments have been devised to test the effect of various combinations of gluing temperature, moisture content, glue-spreading methods and the means of applying the pressure.

The problem of making plywood and solid glued joints from wood which has been pressure-treated with preservatives still enjoys a high priority, and further exploratory experiments have been made, using several typical preservatives and adhesives.

The appearance of furrows in polished blockboards is a common and elusive manufacturing defect, on which considerable time has been spent. Many panels incorporating manufacturing defects have been made up and examined, and it appears that the furrowing occurs as a result of a change of moisture content after manufacture in boards with unglued core-slats, and can usually be avoided by properly drying and edge-gluing the core material. Further experiments necessary to complete the investigation are in progress.

MYCOLOGY

The study of the group of micro-fungi which recently have been shown to cause " soft rot " has gone on during the year, both in the field and in the laboratory. Nine cellulose-destroying species are now known, and further

interesting examples of their activity have been found in boats and elsewhere. They appear to cause much of the decay of partially buried field-test specimens after long periods, and sometimes to be able to develop under conditions less moist than those in which the Basidiomycete group will attack. Experiments on their nutrition show that a correlation exists between the amount of nutrient salts available and the amount of decay caused and it has been confirmed by laboratory experiments that the decomposition of wood in soil is greatly influenced by the available nutrients in the latter.

Decay of timber in boats is still the subject of many enquiries, and it is evident that the value of preservative treatment is not yet fully recognized. The publication of the bulletin on the decay of timber in boats and its prevention will, it is hoped, go far to inform boat builders and owners.

A field experiment on the prevention of deterioration has been completed. Beech logs which, after receiving antiseptic treatment and end painting, were left lying on grass in the shade of a hedge have shown on conversion that their condition, even after a year's exposure, was very much better than that of the untreated controls.

ENTOMOLOGICAL WORK

Most of the long-term work during the year has been done on the biology of the common furniture beetle and the house longhorn beetle. With the former it has been shown that the reproductive organs of both sexes are mature at the time of emergence, and also that most of the eggs are laid during the warm part of the day, the proportion so laid being higher out-of-doors or in the laboratory than in a controlled incubator. Temperature would therefore seem to be most important, although other factors, such as light intensity or fluctuations in humidity may play a part. Other experiments have shown that there was a much greater emergence of adult beetles from wood subjected to a period of cold for a month or two than from that kept at constant temperature.

Work is continuing on the factors influencing the susceptibility of sound wood to the furniture beetle, and it has been shown that in the sapwood of freshly felled Corsican pine the wood is progressively more susceptible towards the outside of the tree. This is presumably bound up with the nitrogen distribution, and experiments are in progress to see if this is so.

A similar series of studies on the life-history and nutrition of the house longhorn beetle is being carried on. Constant conditions of high temperature and humity produce large larvae which, however, appear to be unable to complete their life-cycle. For this, it appears that a period of prolonged cold is necessary, as exposure to short periods at low temperatures did not induce pupation as effectively as did longer periods of cold under normal atmospheric conditions. In experiments on the comparative susceptibility of different zones of Scots pine sapwood, the results were substantially the same as those for the furniture beetle.

With the sanction of the Admiralty and the co-operation of the Pest Infestation Research Laboratory, and a commercial firm, the timbers of H.M.S. *Victory* were fumigated with methyl bromide immediately before the annual emergence of the death-watch beetle, with which her timbers are heavily infested. Although emergence was not completely prevented, it was substantially reduced and a high proportion of the beetles were probably destroyed within the wood before emerging. These results justify a repetition of the fumigation.

WOOD CHEMISTRY

The studies on wood hemicelluloses in co-operation with Professor E. L. Hirst have been continued. It is proposed to re-investigate, using modern methods, the hemicelluloses of oak wood, the early studies on which were made many years ago at the Laboratory. The first products have been prepared during the current year, and have been sent to Professor Hirst for structural investigation.

FIBREBOARDS FROM SECONDARY COLONIAL TIMBERS

Satisfactory hardboards, having the properties of standard hardboard (according to the British Standard Specification), have been made from four commercial timber species from Malaya. Some of them qualified as super hardboard in respect of their strength and water resistance, without receiving any special treatment other than the heat treatment that is now common practice in the industry. Boards made from a mixture of chips of the four timbers in roughly the proportions found in Malayan sawmill waste have good appearance and retain the best characteristics of those made from the individual species. Thus the indications are that the production of boards from mixed hardwood species should not present any additional problems, a matter of some importance in view of the heterogeneous nature of tropical forests.

Other interesting hardboards have been made from African pencil cedar, of which large quantities in the forest are unsuitable for normal commercial utilization. It appears that even after the extraction of most of the cedarwood oil, which is of commercial value, boards made from the heartwood still retain high resistance to fungal attack. Their resistance to termites is being investigated. Considerable interest is being shown in Malaya and Kenya, respectively, in the results of these board-making trials.

MEMBERSHIP OF THE BOARD

On completion of his period of membership, Professor R. D. Haworth retired from the Board in March, 1954. We wish to put on record our appreciation of the service he has rendered to the Laboratory.

We are glad to welcome Professor M. Stacey as a new member of the Board.

R. G. BENNETT,
Chairman.

March, 1955.

REPORT OF THE DIRECTOR OF FOREST PRODUCTS RESEARCH FOR THE YEAR 1954

INTRODUCTION

During the year 1954 no major changes or developments in the work of the Laboratory have taken place, and there has been little alteration in the proportion of time allocated to advisory work, routine investigations and long-term research projects. There has been a further reduction in the testing of new Colonial timbers, and in accordance with the co-operative scheme with the Forestry Commission, a corresponding growth, both in the number of consignments and of species of home-grown timber from the Commission's plantations. In anticipation of the need for grading of the outturn from the home-grown trees, a representative committee from interested sections of the timber industry has been convened to formulate suitable grading rules.

The demand from industry for data and advice remains undiminished, interesting and varied and, together with dissemination of the Laboratory's results, has absorbed a large proportion of the staff time available. Much time, also, has been given during the year to service on advisory and technical committees, especially those concerned with the making of specifications.

Relations with outside bodies and institutions, with industry and the general public, and with other Government departments remain excellent, and active participation on collaborative projects, both academic and applied, remains very satisfactory.

GENERAL

STAFF, BUILDINGS AND EQUIPMENT

The strength and structure of the staff complement have been essentially the same as in 1953, and no major additions or alterations have been made to the Laboratory's buildings or to its equipment.

TOURS ABROAD

The Officer-in-Charge, Timber Mechanics Section, attended the Third Session of the Food and Agriculture Organization Conference on Wood Technology at Paris in May, 1954. During the meeting the Laboratory's specification for the Testing of Veneer, Plywood and other Glued Veneer Constructions was unanimously accepted by the conference as an international standard.

At the invitation of the Deutsche Gesellschaft für Holzforschung, a co-operative research body of the German timber industry, the Officer-in-Charge, Mycology Section, attended in June the biennial meeting of the Society and read there a paper on soft rot.* He afterwards visited the Materialprufungsamt, the Forestry and Timber Research Institute in Berlin and the Forest Products Laboratory in Delft. This meeting was also attended by a senior officer of the

* FINDLAY, W. P. K. & SAVORY, J. G. Moderfaule. Die Zersetzung von Holz durch niedere Pilze. (Soft Rot. The Decay of Wood by Lower Fungi.) *Holz a. Roh-u. Werkst.*, 1954, **12** (8), 293-296.

Wood Preservation Section, primarily for the purpose of discussing the preservation of transmission poles. The visit was made at the request of, and was sponsored by the British Electrical and Allied Industries Research Association.

The Officers-in-Charge, Mycology and Wood Structure Sections, and two other members of the Wood Structure staff attended the Eighth International Botanical Congress held in Paris in July, and took an active part in the proceedings. The visit afforded a unique opportunity of discussing matters of mutual interest with botanists working in related fields. The Officer-in-Charge, Mycology Section, acted as *rapporteur* for the discussions of the decay of tropical timbers, and the Officer-in-Charge, Wood Structure Section, was nominated President of the Section of Wood Anatomy. The wood anatomists attended the meetings of the International Association of Wood Anatomists, which were held concurrently with the Botanical Congress.

The Officer-in-Charge, Composite Wood Section, attended the Hanover Fair as a guest of the Association of British Plywood Manufacturers and visited Spain in October to study the plywood industry there.

PUBLICATIONS AND RECORDS

During the year six new priced publications were issued through H.M. Stationery Office, also two new leaflets and revisions of two others. The priced items comprised the Annual Report for 1953, Special Report No. 8 " The Dielectric Properties of Wood ", and four in the Bulletin series. Bulletin No. 31 " Prevention of Decay of Wood in Boats " was prepared, at the request of naval architects and boat builders, to assist in avoiding risk of damage to wooden craft by fungi and electrochemical action. The recognition, treatment and prevention of such damage are fully dealt with. Bulletin No. 33, " The Strength Properties of Plywood, Part II, The Effect of the Geometry of Construction " is concerned with the development of suitable equations for calculating the bending, tension, compression and shear strengths of any plywood construction.

Of the new leaflets, No. 47 " The Movement of Timbers " gives, for numerous species, the dimensional changes that occur in the seasoned timber when subjected to different atmospheric humidities in service. The timbers are also grouped into three classes, according to the extent of their movement.

Twenty-nine papers (see Appendix II) were published in the scientific and technical press, and ten reports on miscellaneous subjects were prepared for limited distribution.

Work on impending publications has included that on the final stages of the handbooks on hardwoods and on softwoods, and co-operation in the preparation of Part II of the British Commonwealth Forest Terminology on utilization, timber trade and forest products research.

ADVISORY SERVICE

During 1954 there has been the customary large volume of advisory work, of which the varied scope and amount are indicated under the reports on the different sections. The work has been carried on through the usual channels—visits by the Laboratory's staff, visitors to the Laboratory, written replies and reports, queries and answers by telephone and, for routine replies, standard leaflets. The number of enquiries answered by letter during the year was 5614 ; the number of leaflets issued to the public directly or at exhibitions was 37 537,

PROGRAMME OF RESEARCH*

WOOD STRUCTURE

Collection of Timber Specimens

More than eight hundred specimens have been added to the Laboratory's reference collection during the year and a slightly smaller number of duplicate specimens sent out under exchange arrangements. Acquisitions included collections from the Forest Departments of Southern Rhodesia, the Union of South Africa, and Thailand, the Forest Products Laboratory, Madison, U.S.A., the Imperial Forestry Institute, Oxford, the Department of Botany, Cambridge University, Yale School of Forestry, the Peruvian Corporation, and many miscellaneous specimens from official sources, private collectors and the timber trade. Grateful acknowledgment is made to all concerned.

Identification of Timbers

In the course of a year scores of timber samples are referred to the Laboratory for identification because the enquirer is uncertain whether or not the material supplied to him is correctly named. All too often examination shows that his doubts are justified. It must sometimes happen that a parcel of incorrectly named timber is accepted without question and the mistake goes undetected, but in such instances the quality of the end product is liable to be impaired and in the long run the reputation of the particular timber is liable to suffer. The problem arises most commonly in connexion with imported timbers.

Structure and Quality

It is well known that the strength of wood is affected by the degree of lignification of the cell walls, but the way in which the process of lignification is itself controlled by growth factors is obscure. Recent observations have provided evidence that a controlling factor is the illumination received by the leaves.

With a view to elaborating practical methods of selecting timber of optimum quality a survey has been started of the variation in composition of the fibre wall of English ash in relation to site and the growth of the tree. In the course of this work it was observed that the lignin staining reaction was consistently poor in the springwood zone, irrespective of the degree of lignification in the summerwood. Since the springwood in ash is normally formed before the leaves have fully developed it would seem that, although stored food materials can suffice for cambial growth and the formation of woody cells, lignification of the newly formed cell walls might be dependent on some product of current leaf activity. To test this hypothesis experiments have been carried out on ash shoots covered with a light-proof hood for limited periods during the growing season. Subsequent examination of the wood has shown a significant difference in lignification between wood formed during periods of light and of darkness.† This finding points the way to a number of lines of research which should lead to a better understanding of the mechanism of woody growth ; it also has

* Except where otherwise desirable, the trade names of timbers have been used throughout this Report. A reference list of them is given in Appendix III.

† Phillips, E. W. J. Influence of Leaf Activity on the Composition of the Wood Cell Wall. *Nature*, 1954, **174**, 85,

applications in other fields. The opportunity was taken to discuss the matter with leading plant physiologists and anatomists attending the Eighth International Botanical Congress in Paris, and further experiments are being carried out.

Advisory Work in Wood Structure

Many of the enquiries received have involved the identification of timbers, frequently with advice on their quality with reference to specifications or particular uses. The following is a selection of the enquiries dealt with in the course of the year.

At the request of a British firm operating in Peru a consignment of Peruvian timber samples has been examined and advice supplied on their suitability for various uses.

A peculiar softening of the heartwood in young plantation-grown *Eucalyptus saligna* from South Africa has been found to be due to the phenomenon known as brittleheart.

Sample " boxwood " rulers supplied to an education authority and submitted to the Laboratory for examination have been found to be Maracaibo boxwood, ramin, haldu or kwao, podo and hornbeam.

Advice on inspecting ash and hickory hammer handles has been supplied to a public authority.

Information on Paraguayan timbers has been supplied to a Food and Agriculture Organization (F.A.O.) mission to that country.

Two instances of a manufactured product being contaminated by dust—believed to be wood dust—have been investigated.

Specimens of unfamiliar home-grown timbers submitted by timber merchants for identification and advice on utilization have included service tree, apple, *Pinus radiata*, Turkey oak, Lucombe oak, Wellingtonia and *Zelkova crenata*.

Various specimens of tree roots damaging the foundations of buildings have been identified.

The number of external enquiries involving a written reply amounted to 578.

SEASONING

Kilns and Kiln Seasoning

The large kilns have been used during the year for the drying of loads of idigbo, yellow pine, elm, oak, abura and Indian rosewood. The smaller kilns have been used for drying experimental loads of African mahogany, sepetir, dahoma and muchenche. In addition, a load of curved sawn ash chair backs was dried for a firm of chairmakers and one of 1-in. poplar to 8 per cent moisture content for a firm supplying pulleys for export to America. Loads of home-grown oak were kiln-seasoned to determine the effect of temperature on the depletion of the sapwood starch, which is a major component of the diet of the *Lyctus* beetle.

In connexion with the series of tests on the seasoning properties of home-grown softwoods, loads of Sitka spruce, western red cedar and western hemlock have been dried. The Sitka spruce from Wales and the north of Scotland both seasoned with less collapse than similar material from east and west Scotland. The western red cedar likewise was found to be very tolerant of relatively high temperatures as compared with loads previously tested.

The variability of timber and the lack of commercial grading standards for the seasoned material make it extremely difficult to determine what might be termed an optimum drying schedule for any one species. The kiln schedules recommended by the Laboratory are therefore constantly under review and subject to revision as test data are accumulated; among the schedules recently modified are those for home-grown Sitka spruce, African mahogany, and obeche.

High-temperature and Superheated-steam Drying

The fairly satisfactory results of drying Scots pine and some lighter hardwoods at elevated temperatures have already been reported. A number of other species including oak, Douglas fir, balsa and African mahogany have since been dried at temperatures exceeding the boiling point of water 100° C (212° F). The Douglas fir dried at 110° C dry bulb reading and 70° C wet bulb behaved quite satisfactorily but the oak dried in " pure " superheated steam at 110° C collapsed, checked, honeycombed, and distorted so badly as to be rendered virtually worthless. Freshly cut balsa also degraded badly at temperatures above the boiling point.

An extensive series of tests was carried out on the seasoning of African mahogany at temperatures in the neighbourhood of 100° C. The high temperatures induced rapid drying without splitting the timber but varying degrees of collapse or " waisting " of the cross-section of boards occurred. This would lead to a conversion loss in machining, which on these particular loads was estimated as varying between about 5 and 10 per cent of the whole. The commercial significance of such losses, added to the increased rate of deterioration of the component parts of the kiln occasioned by the use of high temperatures, as compared with the savings arising from the decreased drying times obtained, is by no means easy to assess. A report has been issued, and further work is in progress.

Tests on the Effect of Air Speeds on Drying Rates

Work has continued on this series of tests and stacks of 1-in. beech 10 ft wide have been dried in the experimental kiln built for the purpose. Drying lags at different positions across the width of the pile have been determined for various air speeds and a constant drying rate of the inlet samples. The results are being analysed and a report is in preparation. The next effect to be studied is that of reversal of direction of air flow on drying lags and on the kilning schedules that can be applied.

Shrinkage Tests

Shrinkage tests on elm, similar to those previously carried out on beech, have been undertaken and shrinkage values from green to fully-dried plotted against moisture content. The results were in the main similar to those obtained on beech, indicating that samples slowly dried at high temperatures tended to shrink appreciably more than matched samples slowly dried at low temperatures. Shrinkage started at high moisture contents, well above the generally accepted value of the fibre saturation point. Tangentially-cut specimens again expanded initially at high temperatures. Slow drying produced considerably more shrinkage than fast drying and the shrinkage of specimens dried very rapidly appeared to be independent of temperature.

Evaporation Tests

A series of tests has been started to investigate the effects of temperature, humidity and air speed on the rate of evaporation from a free surface of water. The main object of the tests is to determine the coefficient of heat transfer from air and superheated steam to a water surface. Evaporation rates with air and steam temperatures up to 110° C are being examined and suitable equipment is being designed for measuring the magnitude of the various factors involved.

Moisture Gradients in Wood with One Face in Contact with Water

The exploratory experiments of this project were mentioned in the Report for 1952 (p. 13). Since then trays of 1-in. quartered Douglas fir have been filled with water and maintained so that the top face of each has been under water for a period of one year. Some of these trays were painted with two layers of a bituminous paint applied either to the top face, the bottom face, or both faces. In addition, there were untreated controls. The control samples, after having been cut into ten strips across the thickness, showed that a very steep moisture gradient had been induced near the wetted face. A much flatter gradient existed through the bulk of the material with the moisture content of the exposed face roughly equal to the equilibrium moisture content corresponding to the surface air condition. Rates of moisture flow and values of the diffusion coefficients were determined across the thickness of samples (see p. 44).

A relatively thick coating of paint had been applied to the other samples in this series of tests with the result that the moisture content under the paint, remote from an untreated surface in contact with water, was rather above 20 per cent and was hence susceptible to fungal attack.

A coating applied to the top or water face appeared to inhibit the ingress of moisture to such an extent as to set up virtually no moisture gradient within the wood.

A report has been published*.

Miscellaneous Tests

Barrels and bowls of oak and teak designed and manufactured by a firm engaged in the production of fancy cooperage goods for export were subjected to low and high humidty conditions such as might prevail abroad. Serious shrinkage and loosening of the staves occurred in the former conditions and the teak barrels in the latter conditions became wet to the touch. It was discovered that the teak was impregnated with salt and presumably was material salvaged from the sea. Deliquescence was taking place at the high humidity conditions and some corrosion of the metal hoops or bands occurred. This test emphasises the need for care in the manufacture of goods destined for export to foreign climates. Various prototype cabinets for desk telephones have been subjected to varying air humidity conditions and the " movements " and such defects as occurred have been measured and recorded.

* Stevens, W. C. & Johnston, D. D. Moisture Movement through Wood. The Distribution of Moisture in Painted and Unpainted Samples of Douglas Fir when in Contact on One Face with Water. *Wood*, 1954, **19** (10), 400-407.

Wood Bending

Continued attention has been given during the year to the subject of laminated bends of the types used mainly in the building of boats.

A laminated bend of oak 9-in. × 5-in. in cross-section has been made and the resorcinol glue used was cured in a period of 5½ hours by transverse radio frequency heating. Certain practical difficulties involved in the application of R.F. heating to bends of this type were overcome and more uniform heating obtained by applying the radio frequency power parallel to the glue lines. It would probably prove uneconomical to employ R.F. heating for the total period required to cure the glue in a large-dimensioned bend and the possibilities of heating the bend to the required temperature by radio frequency and completing the glue-curing in a heated chamber have been investigated. The results of tests so far carried out on these lines have indicated that it is not possible to obtain consistently good joints with English oak and a resorcinol glue.

A method has been developed whereby bends of large dimensions may be removed from the jigs immediately after the completion of the bending operations and secured only with clamps for the glue-setting process.

Beer Barrels.—Tests to determine whether a suitable substitute timber for oak can be found for the manufacture of beer barrels have been undertaken in co-operation with a firm of brewers. Barrels have been made of brown sterculia and although no great difficulty was encountered in bending and assembling the component parts, the completed barrels could not be considered satisfactory on account of the seepage that took place after filling.

Bending Tests.—Five tropical timbers, including African mahogany from Nigeria and sepetir, have been tested to determine their steam-bending properties, but none could be considered a suitable substitute for the well known bending woods, such as beech.

Large-scale bending tests have been completed on the following species :—

Turkey oak, hornbeam, field maple and sweet chestnut. All these species were found to possess good bending properties, if defects, such as knots, splits, etc., were excluded.

At the request of the Forestry Commission bending tests have been carried out on a consignment of S. American beech (*Nothofagus obliqua*), grown at Bedgebury, Kent. It was found that intrinsically the timber possessed good bending properties, but material of good bending quality was not easy to obtain from this consignment because of the prevalence of knots.

During the year standard tests have been carried out to determine the limiting radii of curvature of laminae cut from twelve different species.

In co-operation with a firm of chair manufacturers experiments have been undertaken to devise an improved technique for making hairpin type bends with straight legs. Radio frequency heating (Plate 1) has been employed for localized softening of the portion to be bent ; also a special steaming chamber has been made in which this portion only of the bending blank may be heated and softened. An improved end-stop device on the bending machine was used in conjunction with these localized softening methods.

A method of producing wooden walking sticks and umbrella handles has been developed in co-operation with a firm of umbrella handle makers so that several sticks can be bent at a time. A suitable type of machine for doing this has been designed.

Bending of Plywood.—Standard tests have been carried out to determine the bending properties of plywood made from five different species, including poplar and adwea. Some data also have been obtained on the bending properties of metal-faced plywood.

The large-scale investigation on the bending and setting of plywood of African mahogany has been continued and the influence of such factors as construction of the ply, methods of softening, etc., on the limiting radii of curvature has been studied.

Advisory Work in Seasoning and Wood Bending

Co-operation with the Trade was maintained throughout the year and visits were made to firms interested in seasoning and bending.

The number of enquiries received during the year in connexion with seasoning and bending amounted to 837.

TIMBER MECHANICS

Testing of Timber for Comparison of Species

The tests referred to in the Report for 1953 (p. 15) on home-grown Norway spruce, Sitka spruce, western red cedar and Douglas fir supplied by the Forestry Commission, on serrette from Trinidad, and on canarium and okwen from West Africa, have now been completed, and full data on strength are available for these species. Tests are in progress on Nicaraguan pitch pine, on dahoma and muchenche from Uganda, and on additional consignments of the home-grown softwoods Sitka spruce, western hemlock and Corsican pine.

The analysis of the data obtained from the investigation to examine the relationship between the test schemes using the 2-in. and the 2-cm specimens has indicated that, so far as hardwoods are concerned, the correlation is good. The ratio 2-in./2-cm of the combined green and air-dry strengths shows close agreement with the " best line " relationship established from detailed statistical analysis. Ratios of from 0·88 to 0·96 for the important strength properties have been obtained and for all practical purposes any error introduced using the simple conversion ratio may be neglected. An important point of interest is that the ratio can be influenced by variations in testing techniques and before it can be accepted internationally testing equipment and procedures will require to be defined more closely. Further tests are in progress with softwoods when the question will be considered as to whether two constants for each property, one for green material and the other to cover the air-dry material, are necessary.

The Structural Use of Timber

The grading and testing for strength in structural sizes of home-grown softwoods have continued during the year. Three consignments of Sitka spruce, from Eggesford in Devon, Gwydyr in North Wales, and Lovat Estate in Scotland, respectively, have been supplied by the Forestry Commission. The spruce from Devon was slightly stronger than that from North Wales, which, in turn, was superior in strength to the material from Scotland. These differences in strength were also reflected in the density of the material and in the strength of the small clear specimens taken from these consignments. Joists converted from the Lovat Estate spruce were of similar average strength to joists of the same grade taken from an earlier consignment from Inverliever.

Long-term Loading

The long-term loading experiments on small glued trusses, begun in 1952, have continued. Observations made after 18 months under load show an increase in deflection of 75 per cent of the initial movement, most of this increase taking place in the first six months. A matched truss with casein glue joints, the test of which was reported in 1952, has been re-tested after storage for nearly 3 years in an unheated building. The truss again carried a load of 7·9 tons without failure. The recovery of deflection was about 90 per cent at working loads.

In the derivation of working stresses it is necessary to take into account various factors which affect the strength of timber and an investigation has been begun to study the effect of long-term loading on ultimate bending strength. Tests are in progress on beams of 2-in. square section of Baltic redwood and Douglas fir which have been assembled as illustrated in Plate 2. The beams in the frame are loaded to a predetermined percentage of the ultimate load of matched control specimens of each species which were tested to ultimate strength according to standard procedure.

The Strength of Struts

The investigations to provide strength data on various sizes and grades of struts of Baltic redwood, Sitka spruce, Douglas fir, and Scots pine have now been completed. The results indicate that a formula of the Perry type represents reasonably well the strength of struts of different species, size and quality, provided that the basic strength values used in the formula are adjusted in proportion to the size of visible defects in the material. A report has been prepared for publication.

The Strength of Connector Joints

Tests have been carried out on a type of timber connector at the request of the manufacturers. A circular shear plate connector of $1\frac{1}{2}$ in. diameter has been tested using Baltic redwood for the test-piece members. Bolted joints with matched material of the redwood have also been tested for comparison.

The Strength of Nailed Joints

A report on the tests started in 1952 on timber joints made with round wire nails has been published*. The investigation has led to the following important conclusions regarding the stiffness and strength of nailed joints. They apply to three-member joints in which the total thickness of members is equal to the length of the nails used and to two-member joints in which the total thickness of members is equal to or greater than the length of the nails used : three-member or double-shear joints are up to 100 per cent stiffer and carry a maximum load of up to 80 per cent higher than the two-member or single-shear joints, the actual difference depending on the thickness of the individual members and on the size of nail used. The stiffness and strength of both three-member and two-member joints are proportional to the number of nails within the range one to four. Two-member joints are stiffest when the thickness t of the nail head-side member is such that $t = 50d^2$, where d is the diameter of the nail. The maximum

* Brock, G. The Strength of Nailed Timber Joints. *Timb. Tech.*, 1954, **62**, 283-286, 333-335, 407-408.

load carried by these joints increases as the thickness of the nail-head-side member is reduced from one-half to one-quarter of the length of nail. The stiffness and maximum loads carried by the three-member joints increase as the thickness of the outer members is increased from half the thickness of the inner member to the same thickness.

An additional investigation has been begun to examine in detail the relationship between density and strength and stiffness in nailed joints. Two-member and three-member joints, made with a single nail, are being tested. The timber used is Baltic redwood and the joint members have been selected so as to cover a wide range of density within each group of test-pieces, and the range of nails 2 in. × 12 gauge to 6 in. × 4 gauge.

The Strength of Plywood

The standard testing of plywood for the determination of strength properties has continued throughout the year. The properties of plywood made from five species, agba, sapele, Scots pine, sepetir and Douglas fir, have been determined. Tests on a sixth species, utile, are in hand.

The experiments to examine the effect of the geometry of construction on the strength properties of plywood have been completed. Simple equations have been determined for calculating the strength values for any plywood construction from the data derived from the standard tests on 3-ply wood. A report covering this work has been published*.

The investigations referred to above enable an estimate of the strength of commercial plywoods to be made with reasonable accuracy. In these plywoods, where the thickness of the veneer is not less than $\frac{1}{16}$ in., the effect of the adhesive is small and may be considered negligible. When the veneer thickness is reduced to less than $\frac{1}{16}$ in., however, the influence of the adhesive on the strength properties will become more marked and, further, it may vary for the type of adhesive used. Experiments have been put in hand to measure the effect of three types of adhesive, a phenolic, a urea and an animal glue, on the strength properties of plywoods made from veneers varying in thickness from $\frac{1}{10}$ in. down to $\frac{1}{50}$ in.

Laminated Construction

A theoretical analysis of the performance of two-species laminated beams has been completed. Two-species beams are made by gluing relatively thin layers of a strong dense wood to a core of a less strong light species. The stronger wood is placed at the regions of greatest stress. The analysis indicates that the working strength is greatest for any particular quantity of material when the compression laminate is thicker than the tension laminate. An equation to define the optimum ratio of thickness for the compression and tension laminates has been established and design procedures determined for the calculation of working strength, modulus of elasticity and ultimate strength for any type of construction. The analysis also has established methods for calculating the depth and ratio of the compression and tension laminates to core thickness of a two-species beam so that (*a*) the cost of the material in the beam will be a minimum, or (*b*) the beam will have minimum weight. The application of the theory is confirmed by the results of bending tests made on sample beams. A report detailing the results of this work has been prepared for publication.

* Curry, W. T. The Strength Properties of Plywood. Part II. Effect of the Geometry of Construction. *Bull. For. Prod. Res., Lond.*, No. 33, 1954.

The Effect of Temperature on the Strength of Timber

The investigation to determine the effect of kiln-drying by superheated steam on the strength properties of timber has continued. Tests have been completed on three species, obeche, abura and Scots pine, each consisting of two batches of matched material. One batch of each pair was selected as a control and kiln-dried using the normal laboratory schedule for the species. The results obtained have indicated that for the particular drying times and temperatures involved, accelerated drying has had no appreciable adverse effect on the static and impact bending strength properties. Supplementary tests of a similar nature are in progress, using another species, African mahogany.

The Depth of a Timber Beam in Relation to its Strength

Tests have begun to examine the effect of varying depth on the strength and elastic properties of timber beams of constant span-depth ratio. Selected Sitka spruce of uniform quality has been used in the investigation.

The strain distribution in the beam is being investigated, using resistance strain gauges. A special single wire resistance gauge has been designed which enables a series of strain measurements to be made at close intervals over the depth of each beam. The experiments are continuing.

Abrasion

The abrasion tests on serrette and sepetir have been completed. Both hardwoods possess high resistance to abrasion and their behaviour under test suggests that both should be very suitable for all conditions of pedestrian traffic and for many types of industrial floor.

Standard abrasion tests have been completed on banga wanga and nkunya at the request of a firm of flooring specialists and of the Conservator of Forests, Uganda, respectively. Both species wear comparatively smoothly under abrasive action and promise to be very suitable for industrial and other heavy-duty floors.

Standard tests on *Ficalhoa laurifolia*, from Tanganyika, to assess its suitability for flooring are in progress.

The continual demand for information on suitable hardwoods for use as flooring in all types of industrial establishment has prompted the issue of a leaflet* on the subject. This publication lists a large number of hardwoods and gives a choice to meet almost all requirements.

Miscellaneous

A number of *ad hoc* investigations have been carried out at the request of manufacturers and Government departments. These include tests on different kinds of joints for use in the manufacture of chair seats, and tests of a number of plywoods and laminated beech boards to assist industrial firms in quality control of material in structural design. Tests have also been made on a limited number of South African grown *Eucalyptus saligna* telegraph poles, to examine the suitability of the species for the purpose, and on wallaba poles for electric transmission lines for the British Electricity Authority. Consignments of home-grown Japanese larch pit-props have also been tested on behalf of the Forestry Commission.

* Hardwoods for Industrial Flooring. *Leafl. For. Prod. Res.* No. 48, 1954.

Advisory Work in Timber Mechanics

The Timber Mechanics Section has continued to give advice to Government departments and industrial firms concerning the structural use of timber and the utilization of new hardwoods, to supply the Timber Development Association with strength and other data, and to advise manufacturers, architects and builders concerning the use of hardwoods for flooring.

Visits were paid to firms engaged in the construction of wooden mine-sweepers and to a Naval establishment to inspect and report on damage to the wooden hull of a motor torpedo boat.

The total number of enquiries in Timber Mechanics during the year amounted to 401.

WOODWORKING

Research in Machining

The blunting of wood-cutting tools has been the subject of further study concerned with the relation of the change in shape and condition of the cutting edges as wear develops to such factors as the material from which the tools have been made, the cutting conditions and the properties of the timber cut. In addition, the effect has been studied of this edge wear on the energy absorbed in cutting and on the finish of the surface produced. Considerable attention has been directed to methods of producing a standard form of high quality edge on the various classes of steel alloy and hard-tipped cutters. Final lapping of the cutter faces was found to give the most satisfactory results after experiments had been made with various special devices. Somewhat similar studies on the lapping of microtome knives were also carried out.

In comparing the resistance to wear of the different types of cutter, it is usually better to machine ordinary classes of hardwood or softwood than siliceous timber, the abrasive effect of which may be irregular or unduly severe on the cutting edges. With the less refractory material long runs of stock must be machined before appreciable wear occurs and thus it is preferable to make narrow cuts to economize in timber. A convenient method of doing so is to plane the edges of boards on a spindle moulder having a power feed and fitted with a disc-type block carrying small cutters. Assessment of the degree of blunting is made in several ways, one of which is to measure the increase in the power needed to cut the wood as wear develops. With narrow stock the amount of power used in the actual cutting is small in comparison with the light running losses of the driving motor and accurate measurement of such small increases is difficult. The use of an integrating meter, for recording the input power in kilowatt-minutes, in conjunction with an electrically operated stopwatch has proved satisfactory for the purpose.

There is considerable difference in the manner in which the cutting edges wear with various metals such as high speed steel, carbon steel, Stellite, etc. Tests have shown the importance of using the correct sharpness angle, especially with the hard-tipping materials. These, being comparatively brittle, need higher values of this angle for reducing the tendency for microscopic fractures to develop at the cutting edges. The quality of the finish of the cutting and clearance faces also control the wear resistance. Scratches formed during the grinding, honing or lapping operations leave minute nicks in the extreme edge. In the cutting

process, extra load is exerted at these points and it is here that blunting is initiated. The ideal edge would be, therefore, the straight line junction of two perfectly smooth faces. Confirmation of this fact has been given by the very extended runs of timber obtained when a superfine finish had been produced on the cutter faces. An interesting feature of the lapping studies, particularly applicable to work on microtome knives, was that scratching of the lapped surface near the extreme edge could be almost obviated by employing only a trailing action during contact.

An improved form of dynamometer was constructed for measuring the torque and thrust in boring. With the aid of high-speed recording apparatus, it has been found possible to measure the loads borne by the various parts of a boring bit. For example, tests made under a particular set of cutting conditions on two hardwoods showed the power demand for an ordinary Jennings type of bit to be distributed as follows :—point, 18 per cent ; spurs, 37 per cent ; main cutting edges, 45 per cent. Some indication has also been obtained of the varying resistance offered by the wood to cutting during each revolution of a boring bit. There is an appreciable difference in resistance, particularly in boring flat-sawn stock, when a single-wing bit is cutting with, across and against the grain. With a two-wing bit such as a Scotch nose, the variation in the combined reaction of the two wings appears to be of sinusoidal form. A difficulty in this study lies in minimizing the masking effect of any small " out-of-balance " in the rotating system.

A series of tests made on quarter-sawn and flat-sawn softwoods and hardwoods showed the torque to have a straight line relationship to the chip thickness and, therefore, to the feed speed. The rate of change of power with chip thickness increased as the spindle speed was raised. The thrust force increased with the feed speed but at a diminishing rate.

Ordinary qualities of commercial boring tools usually need modification or correction to make them suitable for research purposes. Concentricity, adequate clearance at the various cutting edges, correct angles and dimensions are essentials. A special machine was therefore devised for sharpening boring bits. It consists of a fully adjustable clamp for the different sizes and types of bit and a power-driven, spring-loaded reciprocating slip stone for grinding the various cutting faces at the required angles. With its aid, a set of bits ranging in diameter from $\frac{1}{2}$ to $1\frac{1}{2}$ in. was brought to the high degree of uniformity needed for tests to determine the relation of size of hole to power demand.

Other experimental work in sawing and machining has included :—

Stroboscopic and high-speed photographic studies of the cutting action of saw teeth on a special type of machine in which each tooth makes an independent cut in the wood ; the construction of apparatus suitable for advanced research in planing, with which useful information on chip formation has been obtained ; and a preliminary study on hard-tipping of saw teeth and cutters with various special materials.

Full-scale standard tests have been carried out to determine the working and nailing properties of the following species :—

Norway spruce, kiln-dried, from the Forestry Commission, Perthshire ;
Sitka spruce, kiln-dried, from the Forestry Commission (*a*) Kincardineshire, (*b*) Devon, (*c*) Wales, (*d*) Beauly Forest ;
western red cedar, kiln-dried, from the Forestry Commission, Ross and Cromarty ;

Douglas fir, kiln-dried, from the Forestry Commission, Ross and Cromarty ;
yellow pine, kiln-dried, from Canada ;
canarium, kiln-dried, from Nigeria ;
okwen, kiln-dried, from Nigeria ;
African mahogany, kiln-dried, from Nigeria ;
serrette, kiln-dried, from Trinidad.

Advisory Work in Woodworking

Advice has been sought on subjects such as the suitability of machines and tools for particular purposes and methods of improving their performance ; sawing and machining conditions recommended for individual timbers ; design of special machine tools ; furnaces and charcoal kilns ; and conveying equipment for sawdust and wood chips. Interest has also been shown in wood wool and wood flour production, charcoal and wood waste briquetting and the possibility of utilizing the waste to produce resin-bonded sawdust or chip boards. The number of technical enquiries during 1954 was 165 and advice was given to over 70 technical visitors.

COMPOSITE WOOD

Properties of Adhesives

The long-term durability tests on glues for plywood and assembly work continue to yield valuable information. The adhesives now under trial are, however, those formulated five to ten years ago, and since then many minor improvements have been made to existing glues, and several new types have been introduced. With the collaboration of the Adhesive Makers' Panel, a new series of tests has been started which includes modern adhesives in current use, those still in the development stage, and some that are still in the experimental stage. Eleven types have been included in the plywood tests and ten in the assembly work trials. The manufacture of the test material is now in progress.

A considerable amount of preliminary work has been done to evolve a testing technique that will reduce the labour of maintaining these new long-term tests. With the plywood, the establishment of a basic scale for assessing bond quality by the knife test has led to the adoption of this test as the main criterion.

For the assembly work, a new testing method which permits the use of many more samples at each trial will supersede the conventional test to destruction. The test-piece (Plate 3) consists of a quarter-cut and a tangential-grained board bonded together with a selected glue. This laminate is cut into blocks 2-in. thick by $2\frac{1}{4}$-in. square, which are exposed to the weather or to other conditions. The block, by virtue of the differential grain of the two components, is self-stressing under changing moisture contents, and to test whether this stressing has seriously affected the bond, is proof-tested at any desired stage of the experiment by the machine shown in Plate 3, which loads the glued area to a stress equal to 50 per cent of the ultimate green shear strength of the particular timber employed.

The plywood and the proof blocks are being exposed to the weather in an open field or to alternating periods in the " dry " and " wet " rooms of the Laboratory's tropical house. In addition, some samples will be tested by various wetting and re-drying cycles to see if such " accelerated " methods can be linked with the durability of the glues under conditions of natural exposure.

The wider use of laminated members often results in their manufacture having to be undertaken under conditions where means for ensuring close control of the gluing may not be readily available, as for example in the lamination of frames and keels for boats. A series of tests has therefore been devised which aims at defining the tolerance permissible in conditions of manufacture. The test unit consists of three blocks, approximately, 16-in. by 5½-in. by 4½in. thick, composed of $\frac{5}{16}$-in. or $\frac{3}{4}$-in. laminations of either oak or African mahogany the grain of adjacent laminae being arranged as desired. The effect of various combinations of gluing temperature and wood moisture content is being investigated ; in addition the efficacy of post-treatment at a temperature higher than that of setting is being explored. Variations in glue spreading methods and in the means of applying pressure will also be included.

The quality of adhesion is tested by a cyclical wetting and drying treatment based on the Admiralty specification for testing laminated boat members ; after treatment, an assessment is made of the length of splitting occurring in the glue lines at both ends of a block 6-in. in length, and this is expressed as a percentage of the total length of glue lines on the two end sections. The specification allows up to 10 per cent glue line splitting in blocks set at 21° to 38° C and up to 5 per cent for those set at temperatures between 38° and 94° C. Examples of variations in the type of splitting occurring during treatment are shown in Plate 4, and Table I summarizes results so far obtained.

TABLE I

Releation between Variations in Manufacturing Conditions for Oak and Mahogany Laminates and their Behaviour in a Cyclical Durability Test

Moisture content at manufacture	Temp. of gluing °C.	Curing conditions	Delamination				Reference to Plate 3
			Mahogany		Oak		
			Resorcinol glue	Phenolic glue	Resorcinol glue	Phenolic glue	
10-12	25	*	Nil	Nil	Nil	2·5	Nos. 2, 3
10-12	25	40° C for 20 hours	Nil	Nil	Nil	8·5	Nos. 17, 18
15	10	10° C for 3 weeks	Nil	—	73·5	—	—
15	10	10° C for 2 days +40° C for 1 day.	Nil	—	9	—	—
18	25	*	Nil	20·5	53	65	Nos. 29, 30

* Indicates absence of treatment except four weeks' storage at 25° C and 60 per cent r.h. to which all blocks except those glued at 10° C were subjected before testing.

A comparison of the natural durability of the blocks with their behaviour under this cyclical test will be afforded by exposure to the full effects of the weather.

Gluing of Preservative-treated Wood

Studies upon the gluing of wood pre-treated with preservatives have continued. In the Report for 1953 (p. 23) an account was given of a convenient way of treating, by a spray-and-diffusion method, green veneer intended for plywood manufacture, but doubt was expressed of the efficacy of the process to produce

really rot-proof material or a glue bond that would be as durable as one with untreated veneers. A long-term test to decide these questions has been started. Plywood of appropriate species spray-treated and bonded with phenolic resin is being exposed to the weather, the lower edge of each panel being fitted into a slot made from perishable timber, the slot being sufficiently deep to remain wet after being rained upon, and so to encourage fungal growth. Some of the panels and an enlarged view of the " rot slot " are shown in Plate 5. The parts of the plywood above the slot will serve to show the durability of the bond under full exposure to weather.

Exploratory gluing work has been done on veneers and solid wood pressure-impregnated with a range of preservatives. For this, the adhesives employed were those designed for bonding normal wood, i.e. they were not specifically formulated to be compatible with the preservative chemicals. This should be remembered when considering the results, which derive from particular experiments and do not claim to give a full and general statement of performance.

For the plywood tests, veneers of gaboon and African mahogany were pressure-treated with :—

A—4 per cent solution of a fluor-chrome-arsenate mixture.
B—4 per cent solution of a copper-chrome mixture.
C—5 per cent solution of borax.
D—20 per cent solution of commercial ammonium phosphate.

After being kiln-dried at 60° C and conditioned to 8-10 per cent moisture content the veneers were made into plywood, using two phenolic glues and one fortified urea resin. All three lots of plywood were knife-tested in every glue line after cold water soaking, and after three hours' treatment in water at 70° C in the case of the urea glue, and following a day's steaming in a closed cylinder at 30-Lb. sq. in. for the two phenolics. Table II expresses the results as the percentage of glue lines found after these treatments to be of or above the minimum acceptable quality laid down by B.S. 1088 : 1951 " Plywood for Marine Craft ".

TABLE II

Percentage of Acceptable Glue Lines in Plywood Made with Preservative-treated Veneer

Species	Glue	Untreated	Preservative			
			A	B	C	D
Gaboon	PF. 1	91	53	29	—	—
	PF. 2	97	81	92	48	100
	F.U.F.	100	—	—	77	94
Khaya	PF. 1	75	43	—	—	—
	PF. 2	82	55	46	21	94
	F.U.F.	100	—	—	85	92

A dash indicates that no tests were made.

With Preservative D the wood was embrittled by the steaming treatment, and the results are based on the cold-water test only.

Assembly gluing of beech pressure-treated with preservatives has been examined by means of the proof-block test-piece. After the treatment the slab from which the blocks were made were carefully dried and machined immediately before gluing, when the freshly exposed surfaces did not stain absorbent paper when rubbed. Cold-setting phenolic, resorcinol and urea glues were used in conjunction with the following preservatives :—

(1) 3 per cent copper naphthenate in white spirit.
(2) 5 per cent pentachlorphenol in white spirit.
(3) Creosote.
(4) 4 per cent solution of a fluor-chrome-arsenate mixture.
(5) 4 per cent solution of copper-chrome mixture.
(6) 5 per cent solution of borax.
(7) 20 per cent solution of commercial ammonium dihydrogen phosphate.

The performance of these proof blocks was compared with companion sets made from untreated beech at the various stages of an experimental cyclical treatment of the wetting and re-drying type. The findings are given in Table III.

TABLE III

Performance of Three Types of Synthetic Resin Adhesive in Gluing Beech Pressure-treated with Various Preservatives

Type of resin	Preservative with which the glue is:—		
	Suitable	Adversely affected	Unsuitable
P.F.	2	5 & 6	1, 3, 4 & 7
R.F.	1, 2, 3 & 4	5 & 6	7
U.F.	7	1, 2, 5 & 6	3 &4

The tests on both plywood and assembly joints were of a ' laboratory ' type, and their interpretation in terms of natural conditions is being sought by exposing similar material in open fields. Repeat tests employing the same preservatives but different brands of resin are in hand. The present work on preserved plywood enjoys a high priority, and the results of these exploratory experiments are recorded at some length to give an indication of the effect of preservative treatment of veneers on plywood made with representative types of commercial adhesives. The behaviour of other contemporary commercial adhesives or of those of special formulation has yet to be determined.

The complementary work on the methods of impregnating veneers is referred to on page 25.

Properties of Plywood and Blockboard

The investigations into the causes of distortion in plywood during and after manufacture are proving to be very lengthy, and no positive results have so far emerged.

A number of the enquiries on blockboard have been concerned with a defect (Plate 6) which consists of a series of surface depressions running parallel to and

directly above the joints in the core material. These furrows, which are visible on polished boards only under certain light conditions, may show themselves immediately after polishing or their appearance may be delayed for some time.

To determine the cause of the furrowing about eighty blockboard panels incorporating a number of manufacturing variables have been made, and examination shows that furrowing occurs only as a result of a moisture content change from that at manufacture and that it can usually be prevented by edge-gluing the slats of the core before manufacture. When the core slats are assembled without edge-gluing, furrowing to a greater or lesser extent can occur especially if the core material has not been properly dried. The temperature and pressure during manufacture are not critical and " tenderising " the core before assembly does not seem to affect the degree of furrowing. The relative merits of sawn and planed core-stock are now being investigated and the moisture content change at any one level necessary to cause furrowing is being determined.

Trials of Timbers for Plywood Manufacture

Full-scale tests have been made on adwea and sepetir. The former may be suitable for aircraft plywood, and special trials are being carried out.

African mahogany and two *Piptadenia* species have also been tested on a small scale.

A summary has been published of the peeling trials upon 44 species*.

Study of Plant and Equipment

The Report for 1953 (p. 29) stated that the operating temperature of the veneer dryer had been raised from 140° to 170°C and to improve the thermal efficiency the machine had been completely enclosed and the air flow controlled. Steam consumption trials have shown that the cladding has enabled the higher temperature to be attained without any appreciable increase in steam consumption and the higher operating temperature has enabled the drying time for 0·064-in. veneer to be cut by about 30 per cent without affecting the amount of degrade in the dried veneer.

Preliminary experiments with the new veneer slicer have begun.

Advisory Work in Composite Wood

During the year 477 enquiries were dealt with.

WOOD PRESERVATION

Testing of Wood Preservatives

The only satisfactory test for determining the effectiveness of wood preservatives is to carry out a field experiment under conditions similar to those which occur in practice. A test of this type has been in progress since 1929. The test consists essentially of treating wood samples with known amounts of preservative and setting them about half their length in the ground alongside matched untreated controls. The samples are inspected at six-monthly intervals and the effectiveness of the preservative is measured in terms of the extra life obtained for the treated samples.

* KNIGHT, R. A. G. Trials of Timbers for Plywood Manufacture. *Wood*, 1954, **19** (2), 76-80.

As the performance of wood preservatives varies with the locality the tests are being carried out at three different sites, namely, at Princes Risborough, Thetford in Norfolk and Dolgelley in North Wales. At the present time there are about twenty preservatives under test including both high and low-temperature coal tar creosotes, mixtures of creosote and petroleum fuel oil and water-soluble salt preservatives.

So far the high-temperature creosotes have proved to be the best preservatives under test and in twenty-two years less than one per cent of the treated samples have failed. One of the main objects in including high-temperature creosotes in this test was to see if there is any significant difference between the effectiveness of the various types that are normally produced. Up to the present all of them have proved to be highly effective preservatives. The low-temperature creosotes are also proving to be effective preservatives but do not appear to be quite as good as the high-temperature oils. All the modern salt-type mixtures have proved to be effective wood preservatives.

One interesting feature of the results obtained is that preservatives are more effective at Dolgelley than at the other sites. The reason for this is that untreated wood decays much more slowly at Dolgelley and presumably only a small degree of preservative action is necessary to suppress decay so that preservatives are more effective there than at Princes Risborough or Thetford, where conditions are more favourable to decay. These results demonstrate that the effectiveness of some preservatives can vary greatly with the locality where they are used and emphasize the care required in interpreting service results of preserved wood for a single locality, even when the performance of untreated material is available for comparison.

These tests are still in progress but the results obtained during the period 1929-1953 have been set out in a bulletin*.

Sleeper Trials

The experimental sleepers at the remaining three of the original twelve sites were inspected during the year. It is expected that these trials will be completed by next year. During the year reports have been prepared on the condition of the sleepers removed from two sites, namely, Hildenborough and Haddenham. The results obtained at Haddenham (originally an L.N.E.R. site) are of particular interest because they have indicated that the practice of laying the sleepers with the heart face up may give a longer mechanical life than laying them heart face down, which has hitherto been the more generally used method. Throughout these tests the sleepers at the ex-L.N.E.R. sites at Haddenham and Helmdon have split very much less than those at other sites and have always appeared to be in a much better mechanical condition.

A consignment of western hemlock sleepers has been pressure-creosoted at the Laboratory for a service test which is being carried out with this species by British Railways.

Transmission Poles

The experiments mentioned in the Report for 1952 (p. 27) and in that for 1953 (p. 31) on the bleeding of creosoted redwood poles have continued but the work has been held up because of the lack of periods of hot, sunny weather required to induce the bleeding.

* Smith, D. N. Field Tests on Wood Preservatives Used for Pressure Treatment, *Bull. For. Prod. Res., Lond.*, No. 32, 1954.

Work has also been continued on the incidence of decay in inadequately creosoted poles and methods for arresting it, and a report has been prepared for the Supports and Foundations Committee of the British Electrical and Allied Industries Research Association on the prevention and remedial treatment of premature decay in redwood transmission poles.

Treatment of Plywood

Reference has previously been made to the fact that the most promising way of preserving plywood made up of timbers resistant to impregnation is to treat the veneers before glueing. Previous work has shown that dry veneers can be satisfactorily treated with water-soluble preservatives by cold steeping, open tank or pressure treatment. A disadvantage of treating dry veneers, however, is that there is a considerable loss of veneer through splitting which occurs during the re-drying. Attention has, therefore, been given to the possibility of treating the green veneers, and it has been found that gaboon, which is highly resistant to impregnation, can be treated satisfactorily in the green condition by pressure or open tank treatment or even by dipping for a few minutes.

Protection of Wood Against Weathering

Many enquiries are received at the Laboratory for advice on suitable surface finishes for the treatment of various types of external woodwork. The treatment is often required as a cheap substitute for painting or as a method of maintaining the natural appearance or colour of the wood. As there is very little reliable information on this subject service tests have been started on some materials which may be suitable for this purpose.

Advisory Work in Wood Preservation

The advisory work has again covered a wide range, but in the main it concerns the choice of timbers and methods of preservation for a great variety of timber structures, both in this country and abroad, the suitability and properties of materials for use as wood preservatives, the most suitable methods for treating particular timbers and the plant and equipment necessary for impregnation plants.

The number of enquiries during the year in Wood Preservation was 452.

MYCOLOGY

Collections

The collection of wood-rotting fungi has been maintained in good condition, and routine sub-culturing was carried out in duplicate in April and July.

Sub-cultures were also prepared from the set of cultures which had been kept under heavy " medicinal " paraffin since April, 1950. After over four years' immersion under oil without sub-culturing, 476 cultures of Basidiomycetes out of 494 were still alive and capable of renewed growth. Of those that grew, only sixteen appeared to have deteriorated, while the condition of fifteen appeared to be more vigorous than that of the same isolations which had been sub-cultured sixteen times during the interval. Thirteen out of the fifteen fungi

which had maintained their vigour better under oil were those which cause white rots. Fungi which form much acid and liquefy the medium do not conserve so well under oil.

Favourable results were also found with cultures of micro-fungi (Ascomycetes and Fungi Imperfecti) and of 142 such cultures kept under oil for periods of from six to forty months, thirty-seven showed greater vitality than the cultures which had been sub-cultured every three months, sixty-nine showed comparable and seven reduced vigour, but twenty-nine cultures were contaminated. Evidently greater care is necessary to avoid contamination when immersing sporing cultures under oil. Bark-inhabiting fungi, such as *Cytospora* and *Nectria* spp., in particular, retained their original vitality better when under oil than when repeatedly sub-cultured. It is obviously desirable that any cultures which are to be conserved under oil should be in an active and vigorous condition and should be conserved as soon after isolation as possible.

Conservation under oil appears to be a valuable means for protecting a duplicate collection against infection by mites and for retaining the vigour of certain strains which deteriorate rapidly as a result of frequent sub-culturing.

Cultures for identification have been received from India, East Africa and Rhodesia as well as from the Imperial Forestry Institute and the Forestry Commission Research Station.

Additional descriptions of species in culture have been completed and the information transferred to punched cards. Further experience with the punched card method for recognition of cultures has shown its usefulness and it is hoped to publish the descriptions of most of the important species in this form. A sample of the card now in use is shown in Fig. 1.

Physiology of Wood-rotting Fungi

The significance of cellulose-destroying micro-fungi in bringing about the type of decay which has been called soft rot has been further studied. Nine species of micro-fungi have now been shown to cause soft rot under laboratory conditions. These include *Chaetomium funicola* (Plate 7a) and *Bispora pusilla*, a fungus previously reported as the cause of decay of timber in mines in South Africa. Soft rot has rather unexpectedly been found to have developed in beech strips with a moisture content of only 20 per cent kept for two years freely exposed in a chamber maintained at 25° C and 90 per cent relative humidity. Under these conditions Basidiomycetes would not have caused decay.

Much of the decay that had occurred after a considerable number of years' exposure in partially buried field-test specimens that had been treated with wood preservatives was found to be due to soft rot. This was particularly noticeable in specimens of beech and other hardwoods.

The detection of soft rot in thin longitudinal sections of attacked wood is facilitated by examining them under the microscope with polarized light, when the cavities eroded in the cell walls appear as dark areas with pointed ends (Plate 7b).

Further experiments with *Chaetomium globosum* have shown that up to a limit a definite ratio exists between the amount of nutrient salts (particularly nitrogen and phosphate) available and the amount of decay caused by the fungus.

The results of experiments with *C. globosum* on beech sawdust soaked in varying concentrations of Abrams medium are shown in Fig. 2.

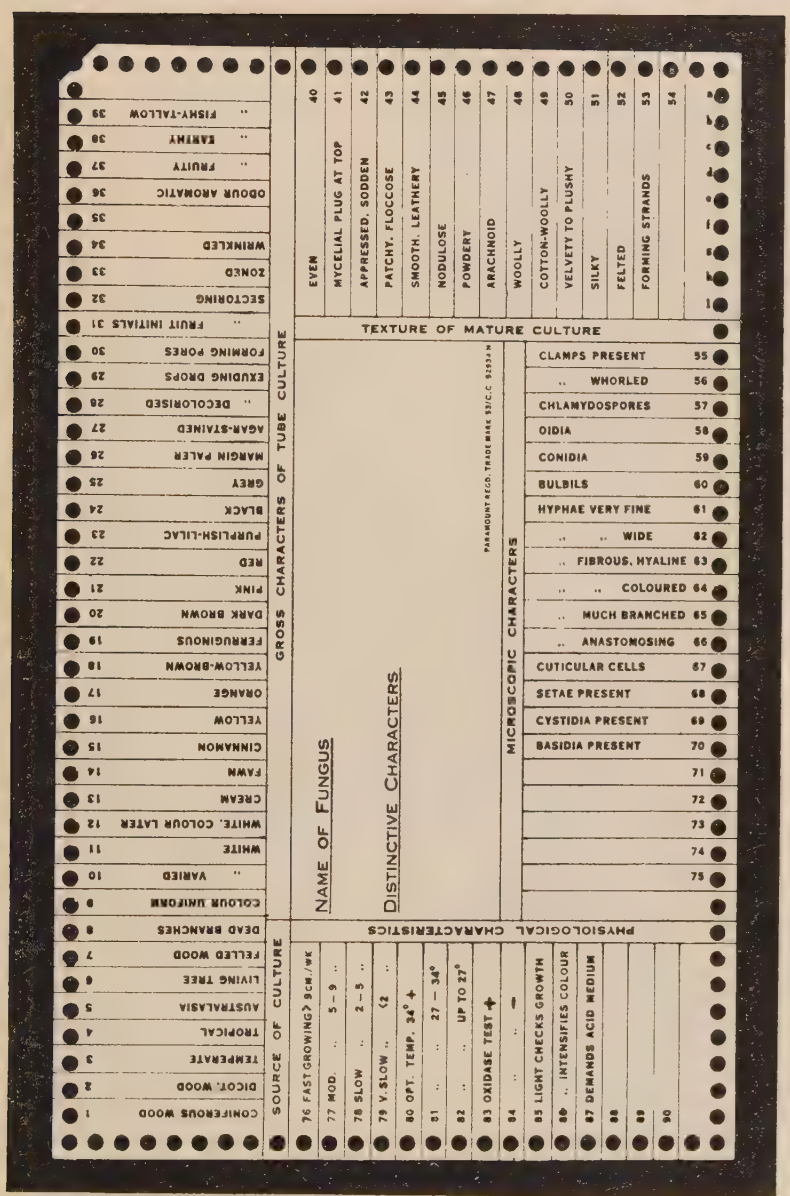


FIG. 1. CARD FOR DESCRIPTION OF CULTURE OF WOOD-ROTTING FUNGI

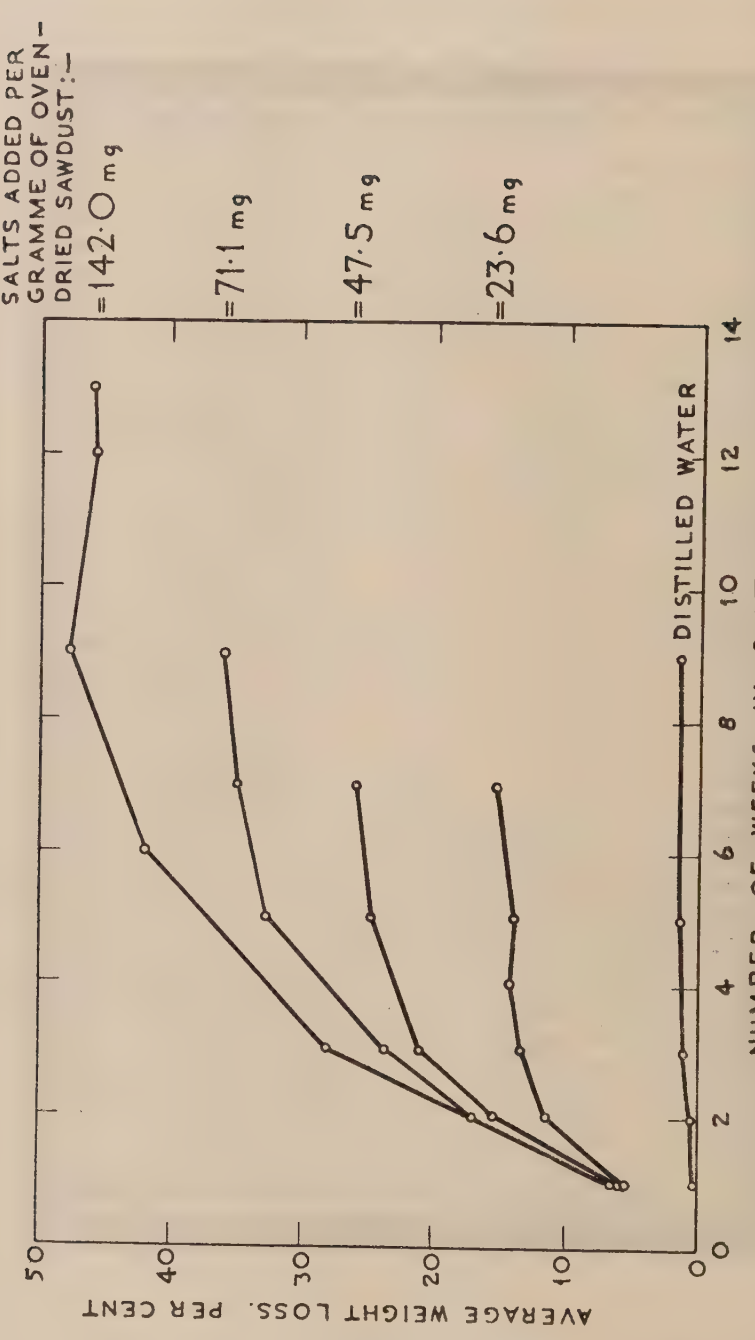
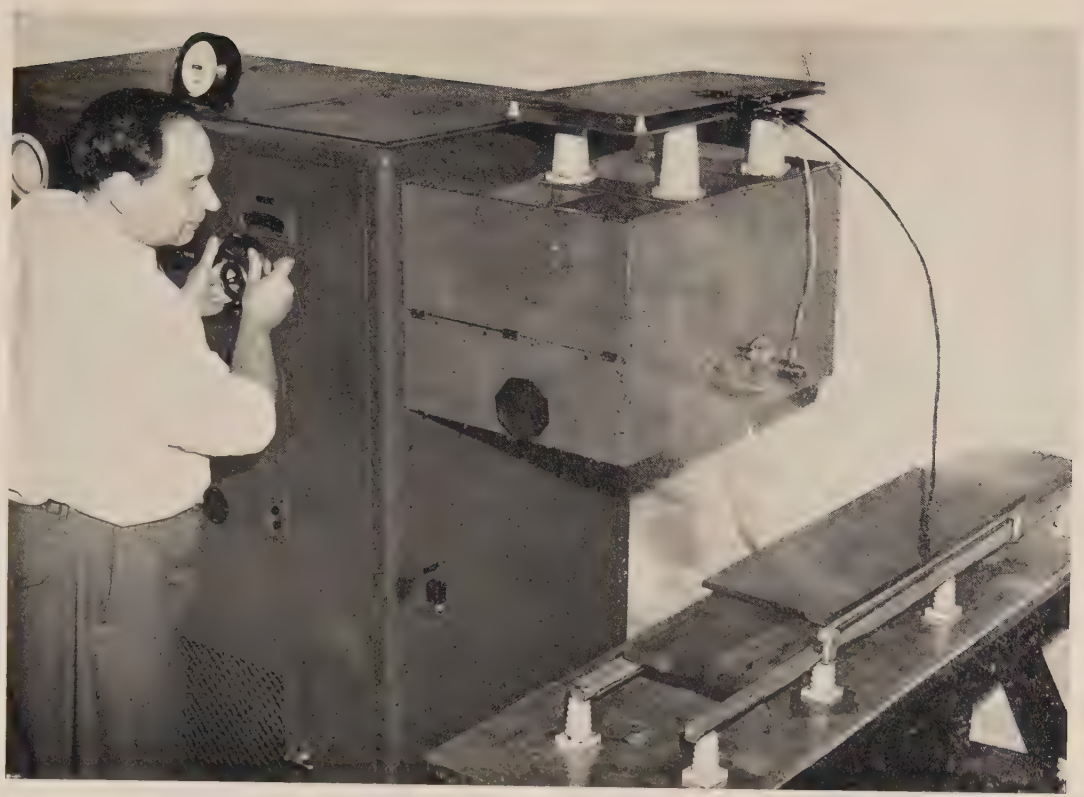


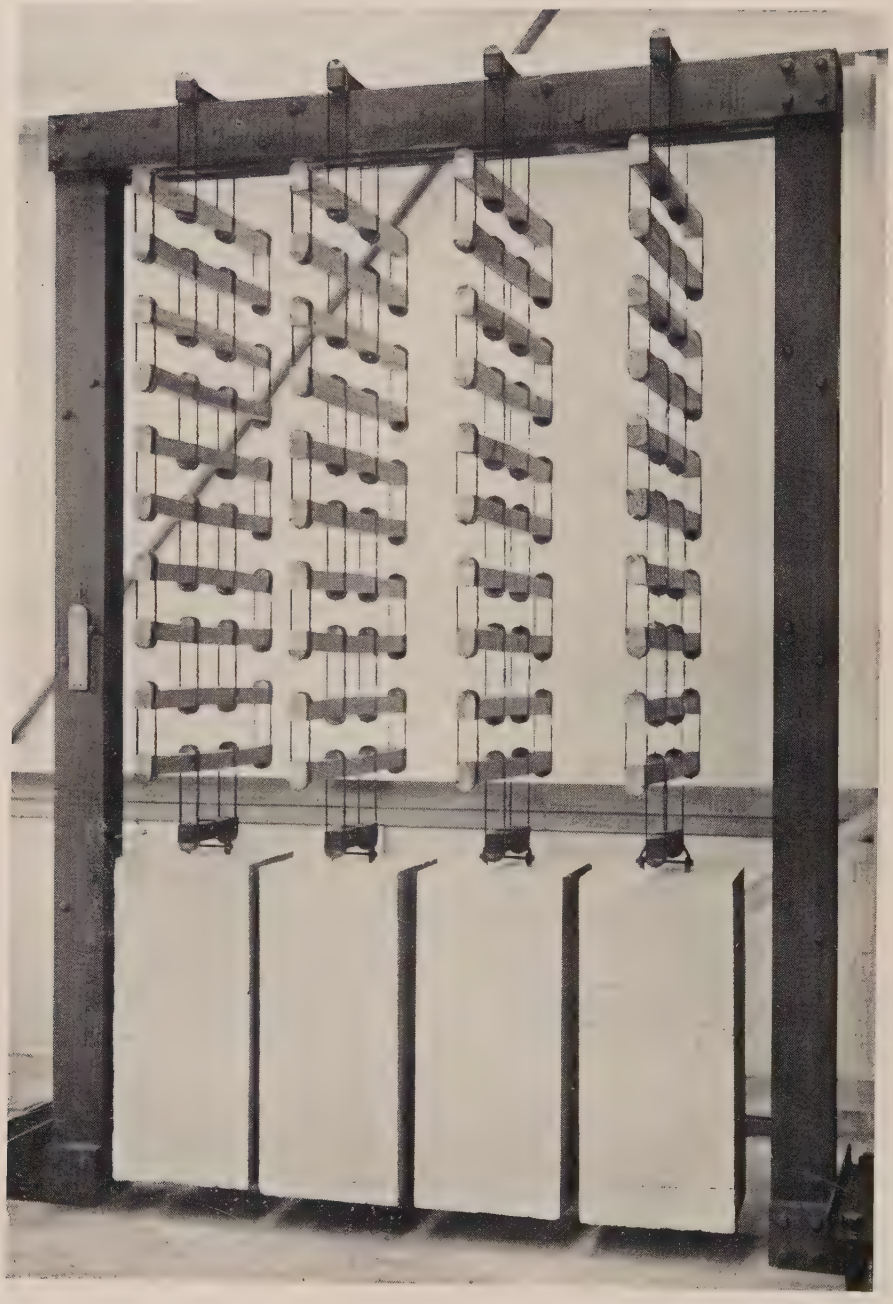
FIG. 2. RELATION BETWEEN AVAILABLE NUTRIENT SALTS AND RATE OF DECAY OF BEECH SAWDUST BY *Chaetomium globosum*

(41226)



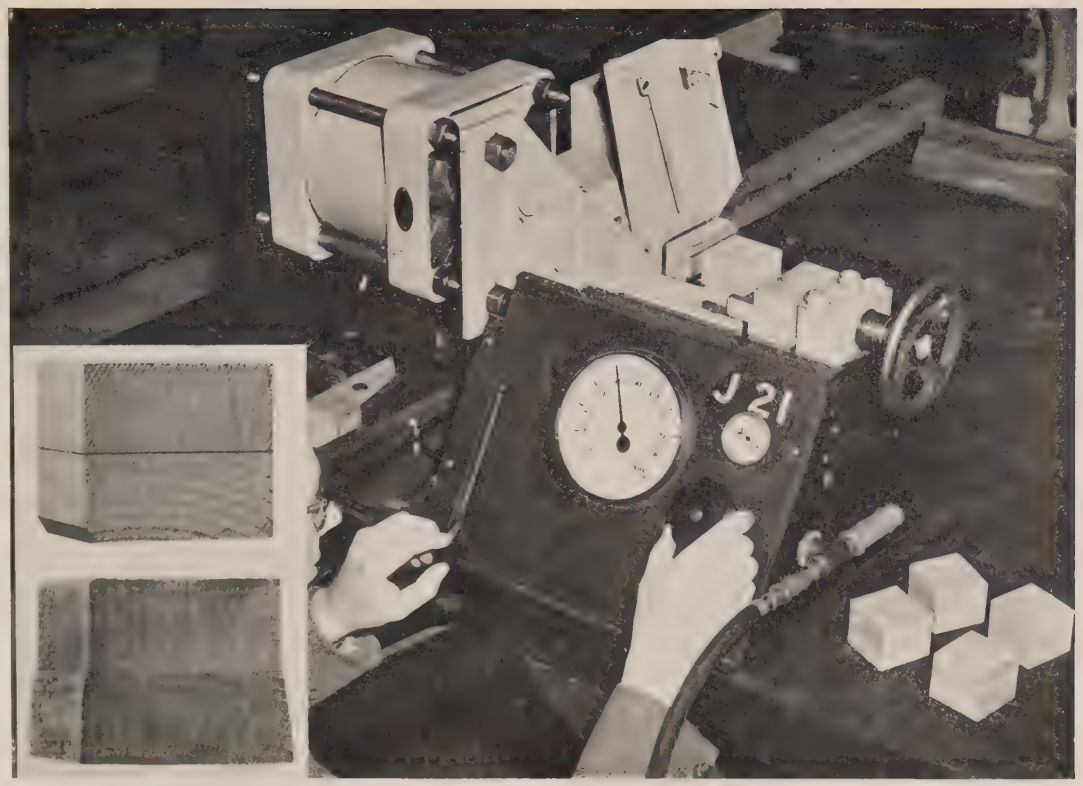
SOFTENING WOOD FOR BENDING BY HEATING IN A RADIO FREQUENCY FIELD

PLATE 1



ARRANGEMENT OF A TEST TO STUDY THE EFFECT OF LONG-TERM LOADING ON ULTIMATE BENDING STRENGTH

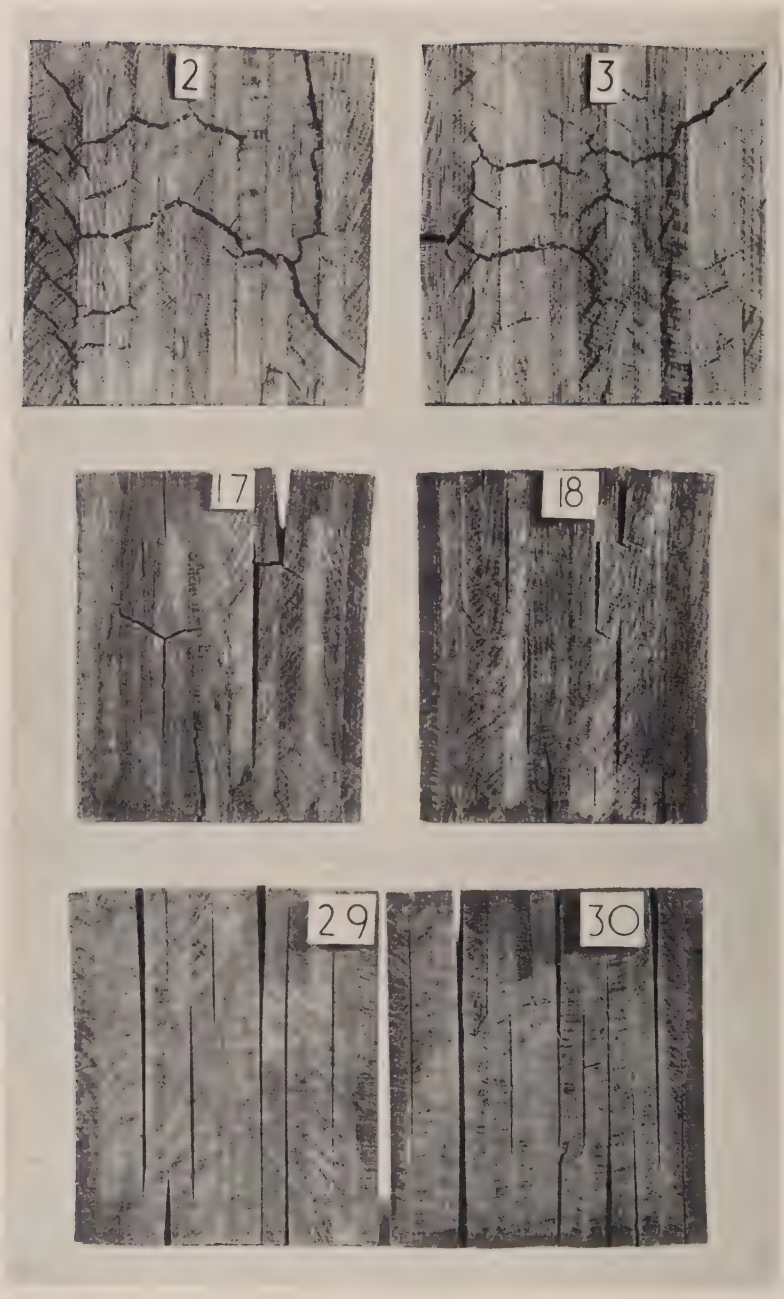
PLATE 2



The inset shows (top) the block as made and in the dry state, and (below) its shape and relative dimensions after soaking in water. Note the effect of differential swelling at the glue line.
In the testing machine, the air cylinder on the left forces the ram against the upper half of the block, the bottom half of which is held in the vice. The proof load is fifty per cent of the ultimate green shear of the timber used in making the block.

PROOF-BLOCK TEST-PIECE FOR TRIALS UPON ASSEMBLY GLUES

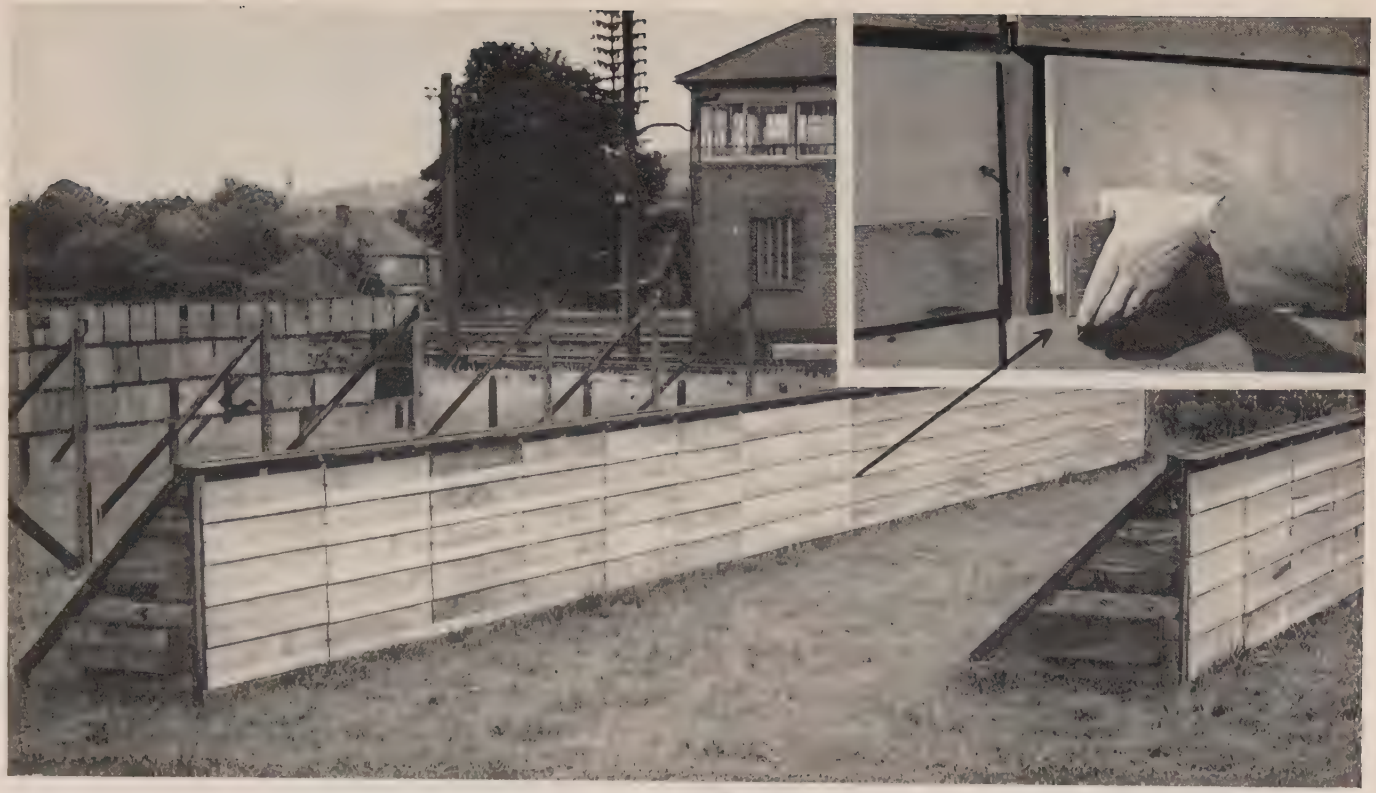
PLATE 3



Examples of the type of splitting occurring during the cyclical treatment of laminated oak blocks glued with resorcinol—(2 and 3) and phenol- formaldehyde resins (17 and 18, and 29 and 30). (*See* Table 1, page 20.)

CYCLICAL TESTS UPON GLUED LAMINATES

PLATE 4



The inset shows a test panel and the ' rot slot ' in which it rests. Phenolic-bonded plywood made with three species and treated with two preservatives is being exposed to the weather in an open field.

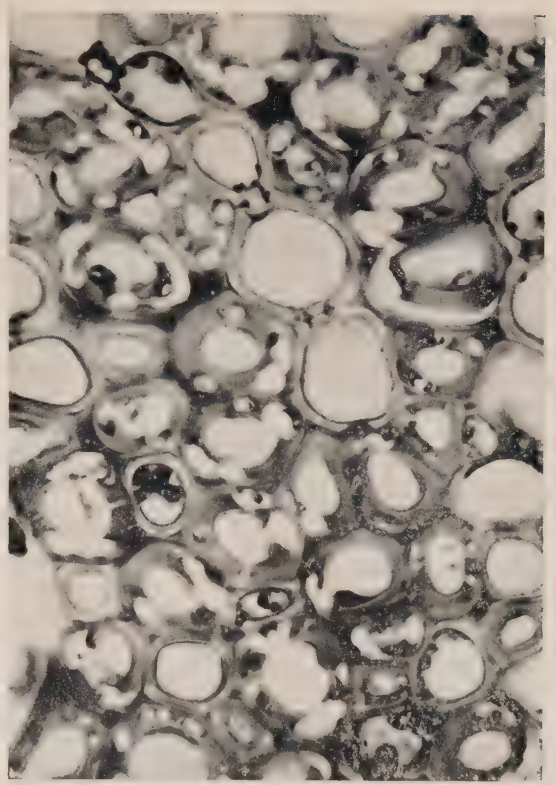
TESTING THE EFFICACY OF PRESERVATIVE-TREATED PLYWOOD

PLATE 5

The appearance of the furrows, which run parallel to the core joints, has been accentuated by the use of oblique lighting.

SURFACE DEFECTS ON VENEERED BLOCKBOARD

PLATE 6



The cavities formed by the fungus can be seen in the walls of the beechwood fibres.

(A) BEECH DECAYED BY *Chaetomium funicola* IN PURE CULTURE. (TRANSVERSE SECTION × 800)

The cavities in the cell walls caused by the fungus appear as dark areas with pointed ends.

(B) SOFTWOOD TELEGRAPH POLE DECAYED BY SOFT ROT. (RADIAL LONGITUDINAL SECTION × 300 AND PHOTOGRAPHED BETWEEN CROSSED POLAROID LENSES)

PLATE 7

On the left a billet treated with pentachlorphenol preparation and end coated with bituminous paint. On the right an untreated billet showing growths of *Stereum purpureum* and other fungi

BEECH BILLETS AFTER 7 MONTHS' EXPOSURE ON THE GROUND

PLATE 8

Very rapid decay of beech can be obtained by exposing beech veneer 0·4-mm thick on Abrams agar ; the ultimate loss in weight of 88 per cent which was obtained suggests that *C. globosum* can eventually remove a proportion of the lignin. Even at this advanced stage of decay the samples retained their shape and could be easily handled during weighing operations without losing any fragments. Since rate of decay by *Chaetomium* appears to be so closely related to the amount of available nutrients, it is to be expected that the decomposition of wood in soil would be greatly influenced by its manurial status. Confirmation of this has been obtained. Blocks of beech wood which were embedded in a moist soil-peat mixture to which a small amount of a balanced fertilizer of the " National Growmore " type had been added decayed more rapidly than in the same soil mixture without the fertilizer.

Active co-operation with the British Electricity Authority in the study of soft rot in cooling tower timbers continues, and a joint inspection of two cooling installations was carried out during the year. The paper describing the results of the earlier investigations has been published and a paper on decay of timber by micro-fungi was presented in German to the Deutsche Gesellschaft fur Holzforschung.

Basidiomycetes

The long-term experiments on the survival of wood-rotting fungi in air-dry wood continue. It has been found that in contrast with the resistant *Lenzites* spp. which were still alive after nine years' storage, the mycelium of *Merulius lacrymans* was unable to survive for more than thirty weeks under the conditions of the test. A note describing these results has been published*.

Laboratory Tests on Wood Preservatives

Standard wood block tests on seven proprietary wood preservatives have been carried out on behalf of their manufacturers, and a number of other toxicity tests have been made on compounded wood preservatives and pure chemicals. The toxicity to fungi of an anti-foaming agent—secondary octyl alcohol—was examined and found to be appreciable.

The suitability of various types of soil for use in the " soil block " contact method was examined, and information regarding this method of test was supplied to the British Standards Institution.

Consideration has been given to the incorporation of a leaching test on a duplicate set of samples in the standard wood block test and a preliminary test is being carried out on blocks treated with sodium fluoride and then leached according to the German standard method before exposure to the test fungi.

Laboratory Tests on Durability of Timber and other Materials

Laboratory tests to determine the decay resistance of canarium, sepetir sapwood, okwen, serrette and African mahogany have been completed. The durability of cherry wood is being examined in a test on a somewhat more comprehensive scale than usual since preliminary results suggest that it may be a much more durable timber than it is reputed to be.

* Findlay, W. P. K. & Badcock, E. C. The Survival of Dry Rot Fungi in Air-dry Wood. *Timb. Tech.*, 1954, **62**, 137-138.

134, f-563

Samples of wallboard prepared from East African pencil cedar (see p. 42) have been exposed to fungal attack under controlled conditions and considerable differences were found between samples made from sapwood and heartwood, those made from the latter being almost immune from attack.

An extract of mora saponin prepared from morabukea has been examined and found to be strongly toxic to fungi.

At the request of the Joint Fire Research Organization four samples of fire hose treated with a preservative have been tested against *Chaetomium globosum*.

Dry Rot Investigations

Tests of materials for sterilization of walls infected by *Merulius* have been continued in co-operation with the Building Research Station. Sodium fluoride (4 per cent solution), magnesium silicofluoride (10 per cent solution) and copper sulphate (10 per cent solution) did not prevent overgrowth of *Merulius lacrymans* when applied to cement-lime mortar. Under these conditions 0·8 per cent sodium pentachlorphenate solution, 0·1 per cent mercuric chloride, 2 per cent phenyl mercuric dinaphthylmethanedisulphonate, 0·1 per cent tri-ethyl tin hydroxide, a number of proprietary preparations of organic mercury compounds and copper-8-quinolinolate were all effective in preventing overgrowth of the test-pieces of mortar by the fungus. Further tests will be carried out on sodium pentachlorphenate to determine its permanence on mortar.

Further tests on timber treated with sea water show that if the wood has been thoroughly soaked with sea water it shows an appreciable degree of resistance to attack by dry rot fungi but that the resistance of wood merely wetted on the surface is not enhanced. On the other hand, wood impregnated with sea water is more hygroscopic than normal wood and would attain a moisture content suitable for fungal growth in a less humid atmosphere. Further tests to assess the relative importance of these factors are in progress.

Decay of Timber in Boats

Further examples of soft rot in boats have been observed, the most severe case having led to the failure of $\frac{3}{8}$-in. elm planking in a naval whaler.

Many enquiries on the subject of decay of timber in boats are still received and it is evident that the value of preservative treatment for the less durable species used in boat building is not yet fully appreciated. The bulletin on decay of timber in boats and its prevention has been published.*

Assistance in the preparation of a memorandum on prevention of decay in refrigerated ships was given to the Refrigerated Cargo Research Council.

Sap-stain Investigations

Further tests have been made to determine more exactly the temperatures necessary to kill the *Diplodia* spp. which cause sap-stain in so many tropical woods. In material infected in the laboratory the fungus was killed when subjected to a temperature of 55° C for $\frac{1}{2}$-hour but it survived 4, but not 16, hours' exposure to a temperature of 51-52° C The fungus proved to be more resistant in naturally infected material (in which its mycelium was probably more mature), surviving for 4 hours at 58° C but succumbing after $\frac{1}{2}$-hour's exposure to 60° C.

* Savory, J. G. & Packman, D. F. Prevention of Decay of Wood in Boats. *Bull. For. Prod. Res., Lond.*, No. 31, 1954.

1 34 1562

It takes only about 10 minutes for the centre of 1-in. cubes of ramin at 21 per cent moisture content to reach a surrounding temperature of 60° C but in preliminary experiments in a timber-drying kiln it was found that the fungus had survived 4 hours at 61° C. The practical implication of this work is that it is probably necessary to expose hardwoods stained with *Diplodia* to a temperature of about 65° C (149° F) for at least one hour to ensure killing the staining fungus and thus prevent staining of the timber during its subsequent drying.

Measurements of the rate of growth of *Diplodia theobromae* along the grain in ramin have been made, using sticks 15-cm in length which had been coated on the outer surface with wax to prevent superficial growth of the fungus. In 19 days at 22° C the fungus had penetrated throughout the length of the sticks, indicating a daily advance of nearly 1-cm per day. Since the fungus can progress so rapidly through the wood it is easy to understand how superficially infected logs may become severely stained to a considerable depth during a voyage of many weeks' duration at tropical temperatures.

The toxicity to staining fungi of tri-butyl tin oxide has been examined and found to be somewhat lower than that of the sample of tri-ethyl tin hydroxide previously tested.

Following reports that treatment with solutions of benzene hexachloride in white spirit had stimulated the development of mildew on woodwork, laboratory tests have been set up using old woodwork tunnelled by the furniture beetle. So far no evidence has been obtained that treatment of woodwork with insecticides containing BHC does in fact stimulate the development of moulds.

Prevention of Deterioration in Logs of Perishable Species

The field experiment with beech logs that had received various treatments referred to in last year's Report (p. 35) has been completed. Sample billets were sawn up after lying for 3, 6, 9 and 12 months on the grass in the shadow of a hedge. The condition of those which had received antiseptic treatment, and which had, in addition, the ends coated with a bituminous paint, was very much better than that of the untreated controls (Plate 8).

A second experiment on the protection of beech logs was begun early in the year and a similar test on a smaller scale with small oak logs is in progress.

Advisory Work in Mycology

The number of advisory enquiries received during the year again shows an increase over the previous years, 1,157 having been dealt with by letter. As usual most concern decay of timber in buildings and boats. Many enquiries related to deterioration of shipments of timber in which the enquirer was anxious to know the origin and time of incidence of the defect. Decay of bodywork in vehicles has also been the subject of a number of enquiries.

The Ancient Monuments Branch, Ministry of Works, have submitted for examination samples of wooden Saxon bowls, Roman writing tablets and other wooden articles of antiquarian interest.

Among unusual enquiries received were those relating to a vigorous growth of *Pyronema* on a ceiling, on plaster over strawboard ; deterioration of coir ropes in storage ; and decay of timber in laundry trucks, in chicken incubators and in cricket bat willow clefts which had been exported. Felt from a leaking roof was found to have been penetrated by fructifications of *Schizophyllum commune*, which appeared to have been attacking some constituent of the felt.

ENTOMOLOGY

Investigations on Lyctus Powder-post Beetles

Starch Depletion in Kiln-dried and Air-dried English Oak.—Starch grading of kiln-dried and air-dried English oak boards used in a test begun in 1953 has been completed and has shown that significant depletion of starch has occurred after both types of treatment. An experiment on a larger scale has been started using quarter-sawn boards cut from green English oak logs felled early in 1954. Some of these were piled for air seasoning and others for drying in a model kiln. The results await examination of the boards from the air-seasoning pile.

This test has been supplemented by repeating a low-temperature kiln treatment (40-41° C) under saturation conditions as previously carried out (1936). Matched boards have also been placed in constant temperature and humidity rooms for controlled rates of drying and to act as a check on the behaviour of the air-seasoning piles. On completion of these experiments, using different methods of drying, an attempt will be made to correlate the results with those following exposure to infestation by *Lyctus*.

Prevention of Infestation in Sawn Logs.—Sixteen months after treatment in May, 1952, with benzene hexachloride, applied by spray or as a water-dispersible powder and oil emulsion at concentrations of 0·5 and 0·325 per cent gamma isomer, exit holes were found to be present only in boards sprayed with the water-dispersible powder at the lower concentration ; slight attack in the form of larval tunnels was evident in the other material.

A 10-second dip treatment in an oil emulsion at a concentration of 0·325 per cent gave complete protection, whereas a single board dipped in the water-dispersible powder at the same concentration was attacked.

All the treated material showed much less damage than the untreated controls in which 90 per cent of the boards became infested.

The Common Furniture Beetle (Anobium punctatum)

General Life-history Studies.—General biological work on the life-history of *Anobium* has been continued throughout the year ; further records of emergence, which was later than normal, have been obtained and a close relationship noted between peaks of emergence and temperature. A further number of dissections of the reproductive organs have been made and it has been found that the gonads of both sexes are mature at the time of emergence of the beetles. Subsequent changes are similar to those undergone and already described in the closely related death-watch beetle *Xestobium rufovillosum* and in *Ernobius mollis*. A small-scale experiment has shown that between 10 a.m. and 6 p.m. out of doors 83 per cent of the eggs were laid, and 72 per cent under laboratory conditions. In an incubator only 50 per cent were laid during this period. Whilst it seems probable from these results that temperature is an important factor in determining the time of egg-laying, the effect of light intensity or fluctuations in humidity may also be significant.

Throughout attempts during the last four years to breed the furniture beetle under constant conditions of temperature (22° C) and humidity (86 per cent) in incubators, although larvae either fully grown or of exceptionally large size have been reared from the egg, few have pupated. An experiment was made to try the effect of submitting such larvae to low temperatures. Samples of sapwood

of Corsican pine believed to contain fully grown larvae, together with other samples into which such larvae had recently been transferred, were subjected over a period in spring, 1954, to a low temperature at the Pest Infestation Research Laboratory. The temperature was gradually reduced to 3° C over a few days and maintained there for one or two months. Later, some of the samples were returned to the original incubator conditions of 22° C and 86 per cent relative humidity and others to laboratory conditions. Although a small emergence occurred during the summer, 1954, from control samples kept under incubator conditions throughout, a much larger number emerged from samples subjected to the low-temperature treatment, particularly from those subsequently stored under laboratory conditions. These results appear to confirm the indication that such constant conditions of temperature and humidity are not suitable for the normal completion of the life-cycle of *Anobium punctatum*.

Investigations on Infestation in Sound Wood.—Particular attention has been given during the year to a study of the factors governing the susceptibility of sound wood to attack by the furniture beetle. An experiment was planned to examine and extend the work undertaken by Becker* on the differences in susceptibility to attack of different zones of sapwood. Sapwood cut from discs of freshly felled Corsican pine was divided into three zones and exposed for egg-laying by *Anobium* in 1952. After 20 months it was found that the outer zone was far more suitable for larval development than the middle, which in turn was more suitable than the inner zone. These results may be explained by the nitrogen distribution in the zones, since analysis of matched samples shows a decreasing nitrogen gradient from the periphery, of a somewhat similar order to that obtained for larval weight across the three zones.

Additional material from the outer zone was extracted with acetone, and with water at 60° C and 100° C and subsequently exposed to infestation. The acetone treatment, which removed mainly resinous contents, was found to have little effect on susceptibility to attack, whereas prolonged soaking in water at 60° C greatly reduced it, and after soaking at 100° C the wood was rendered even more unsuitable. The chemical effect of these water extractions is not fully understood ; the yield of reducing sugars in the extracts indicated that in addition to removal of traces of free sugars, some hydrolysis of the wood substance occurred, greater at 100° C than at 60° C, and also that much mineral matter was removed, particularly at the higher temperature. Furthermore, although these treatments may remove only a negligible amount of nitrogen they may alter the remainder to an unsuitable form and also bring about physical or chemical changes of the wood substance, e.g. partial delignification. These conclusions are, however, tentative and further work is planned.

The results of an egg-laying preference test on natural sawn surfaces of English oak sapwood and heartwood extracted with water at 60° C and 100° C, acetone and ether, have shown that in sapwood little choice is exercised between material extracted in these various ways but that unextracted material is preferred, whereas in heartwood all methods of extraction appear to render blocks more suitable for egg-laying than unextracted controls.

Information is lacking on the susceptibility of light tropical hardwoods to attack by the common furniture beetle ; an experiment has therefore been set

* Becker, G. Okologische und physiologische Untersuchungen uber die holzerstorenden Larven von *Anobium punctatum* de Geer. *Z. Morph. Okol. Tiere*, 1942, **39** (1), 98-152.

up using small blocks cut from zoned material and samples of larger dimensions of agba, obeche and white afara. Samples of Corsican pine sapwood are being used as controls.

Investigations on Infestation of Decayed Timber.—Experiments upon the effect of decay on the suitability of wood for attack by the common furniture beetle are still in progress. Samples of sapwood of Turkey oak decayed by *Fomes cryptarum* and impregnated with 1, 2 and 5 per cent solutions of peptone before exposure for egg-laying in 1953 have now been examined. The results indicate that samples treated with 2 per cent peptone are probably the most suitable for larval development. Examination of Scots pine sapwood, both sound and decayed, exposed for egg-laying under fluctuating conditions of temperature from 25° C to 28° C and of relative humidity from 75 to 93 per cent, indicate that such conditions are not unsuitable for egg-laying and initial penetration by first-stage larvae.

The Death-watch Beetle (Xestobium rufovillosum) *and H.M.S. Victory*

Further enquiries have been made as to the practicability of using radiation treatments for the destruction of the death-watch beetle in the timbers of H.M.S. *Victory*. A meeting at Princes Risborough of specialists from the British Museum Research Laboratory, the National Gallery and the Isotope Division, Atomic Energy Research Establishment, Harwell, endorsed the conclusion previously reached that insufficient information was at present available on radiation treatments of wood to consider their application. It was decided that studies on a laboratory scale were necessary to obtain precise data on radiation dosages for the destruction of wood-boring insects or to produce sterility in the adults. A preliminary programme of work has since been agreed with Dr. W. Wild at Harwell, and experiments will be carried out with *Lyctus* powder-post beetles, of which suitable material can readily be prepared.

Admiralty sanction was obtained by the Portsmouth authorities for fumigation of the ship with methyl bromide, suggested by this Laboratory in consultation with the Pest Infestation Research Laboratory as a means of improving measures of control which have been carried out over a period of years. The fumigation was undertaken by a commercial firm in co-operation with the two Laboratories in April, 1954, immediately before the annual emergence of beetles. The results of the treatment are being determined on the basis of numbers of death-watch beetles which emerged later during April, May and June, and also by examination of test insects placed before treatment in various positions in the ship.

Counts of beetles found on the ship during the emergence period were made by the ship's staff as in previous years. Although emergence was not completely prevented by the fumigation treatment, it has been very substantially reduced, indicating that a high proportion of the beetles is likely to have been destroyed within the wood before emerging. The annual emergence of death-watch beetles in 1952, 1953 and 1954 was 7713, 5200 and 938, respectively.

These results justify a repetition of the fumigation, particularly in view of the information and experience gained in this type of treatment for a unique instance of widespread infestation by the death-watch beetle in massive timbers inaccessible to liquids.

The House Longhorn Beetle (Hylotrupes bajulus)

Occurrences.—New records of damage by this insect have been noted from two additional centres in Surrey where there have also been further instances of attack in districts known to be infested. A property in a south-west London suburb in which active infestation had been reported was examined but no evidence of present activity was found, the damage being of long standing and the insect now extinct. Similar instances of old attack in the London area have come to the notice of the Laboratory from time to time.

Life-history Studies.—The data obtained at the Labaratory on emergence, egg-laying and hatching of the house longhorn beetle during the summers of 1951-53 have been analysed and collated with a view to publication of an account of the breeding habits of the insect in the United Kingdom.

Experiments on the rate of larval growth under different conditions of temperature and humidity have been continued. As in the case of the common furniture beetle, constant conditions of high temperature and humidity appear to be unsuitable for pupation and completion of the life-cycle, probably owing to the absence of diapause following periods of low temperature in the natural habitat of the insect. The effect of transferring experimental samples containing the large larvae obtained under the constant conditions from the incubator to insectaries out of doors and of various periods of exposure to low temperatures has been investigated with the co-operation of the Pest Infestation Research Laboratory. The results so far obtained suggest that exposure of these larvae for short periods to low temperatures, e.g. 0° C, or fluctuating between — 9° and — 17° C, for 16 days and return to the incubator did not induce pupation as effectively as longer periods of cold under normal atmospheric conditions.

Nutritional Studies.—Experiments on the lines of those in progress with the common furniture beetle have been continued to compare the suitability of different zones of sapwood of Scots pine for larval growth and to determine the effect of removal of extractives by leaching with hot water (60° C and 100° C) or with acetone. It is of interest to note that the results so far obtained with both insects are very similar.

The statement has recently been made that house longhorn larvae are capable of attacking hardwoods, and records have been published of their presence in oak structural timbers. A small-scale experiment has therefore been set up to investigate the progress of larval development in the sapwood of oak as compared with that of Scots pine. When given equal opportunities of entering either of these timbers some larvae did attack the oak. Larvae artificially introduced into oak sapwood have, with a few exceptions, started tunnelling, the bore dust produced consisting of cylindrical pellets not typical of the non-compacted powder associated with the workings of this insect in softwood.

Other Longhorn Beetles

A test has been set up to determine the value of a 2 per cent emulsion of DDT miscible oil in water, as recommended against *Lyctus* (see Forest Products Research Leaflet No. 43) for the prevention of infestation by *Callidium variabile* commonly found on the edges of sawn boards of English oak and beech, where bark is present.

A small stock of timber actively infested by the introduced Indian longhorn beetle, *Trinophylum cribratum**, has been obtained during visits to a timber yard in the London district. Adults have emerged and it is hoped to rear a stock of this insect for use in future biological experiments designed to assess the potential importance of this beetle as a timber pest in the United Kingdom.

Laboratory Tests of Wood Preservatives

Larval Transfer Technique—Anobium punctatum.—Work has continued on the development of improved technique for the use of the larval transfer method of evaluation of wood preservatives and insecticides. It has been the custom to obtain *Anobium* larvae for this purpose from naturally infested plywood from buildings or other sources. Transfer of larvae above 2·5 mg in weight to test samples stored at 22° C and 85 per cent relative humidity resulted, as might be expected, in early pupation. As larvae below 1·0 mg are difficult to handle, specimens between 1·0 and 2·5 mg have been utilized in this work but these form a very small proportion of the total population of the insect in infested plywood.

Preservative Tests.—Work has continued with the larval transfer technique for the evaluation of wood preservatives, using larvae (1·0-2·5 mg) of the common furniture beetle and of newly emerged larvae of the house longhorn beetle. In this work the test samples were selected at random without reference to the zone of sapwood from which they were cut. The following is a summary of the results so far obtained with Scots pine sapwood impregnated with a water-soluble preservative (fluor-chrome-arsenate) at concentrations of 0·5, 0·18, 0·0675 and 0·025 per cent.

Anobium larvae at 22° C and 85 per cent relative humidity : In general the results suggest that under the conditions of the experiment a minimum retention of 1·4 mg/cc. of the water-soluble salt is necessary to arrest larval development within a comparatively short period.

Hylotrupes larvae at 25° C and 75 per cent relative humidity : As in the case of the common furniture beetle, first-stage larvae of the house longhorn beetle are able to survive for long periods in blocks treated with 0·25 per cent of the preservative but a concentration of 0·5 per cent, equivalent to a retention of 3·8 mg./cc., is sufficient to kill these larvae in 12 weeks.

Borax.—A series of similar tests has been started using zoned sapwood of Scots pine impregnated under pressure with water solutions of borax at con-trations of 1·0, 0·5, 0·1 and 0·05 per cent.

Pentachlorophenol.—A test is in progress to assess the preservative value of pentachlorophenol with particular reference to the duration of its effect. A number of oak sapwood samples has been treated by dipping for one minute in chloroform solutions at concentrations of 5·0, 2·5, 1·0 and 0·5 per cent (weight/volume). Sets of these samples have been exposed to *Lyctus* at 25° C and 75 per cent relative humidity one month and five months after treatment. Infestation was prevented by the two higher concentrations but attack took place at the two lower figures. Untreated control samples were severely infested. A third set exposed to attack after twelve months' storage at room temperature has not yet been examined.

* Duffy, E. A. J. *Trinophylum cribratum* Baker (Col. Cerambycidae). A New Indian Pest of British Timber Yards. *Ent. Gaz.*, 1953, **4** (4), 254-264.

Other Tests

In addition to the above, laboratory tests are in progress to evaluate the preservative value of a number of preparations including aldrin, dieldrin and orthodichlorbenzene.

Investigations on Ambrosia (Pinhole Borer) Beetles in West Africa

The West African Timber Borer Research Unit of the Colonial Office is at present concerned with investigations on ambrosia beetles (Platypodidae and Scolytidae) in the Gold Coast. Contact has been maintained with the officer in charge of the Unit, programmes of work exchanged and comments and suggestions forwarded.

Investigations at Princes Risborough were in abeyance until August, 1954, owing to shortage of staff. Material infested by the oak pinhole borer, *Platypus cylindrus*, was, however, obtained and observations made on the activity of the insect in relation to temperature conditions throughout the year.

An opportunity has been taken of co-operating with a commercial firm in setting up a small-scale test of insecticides for the treatment of oak logs to prevent infestation by the oak pinhole borer in an East Anglian timber yard.

Sterilization of Insect-infested Timber by High Frequency Treatments

The destruction of wood-boring insects by H.F. electric currents offers an attractive means of eradicating infestation in timber *in situ*, but no reliable information is available on techniques or exposures. A series of experiments to investigate these matters has been planned in collaboration with the British Electrical and Allied Industries Research Association and samples of English oak infested by *Lyctus* powder-post beetles have been prepared for a series of tests. The dimensions of the samples have been chosen to enable them to be used in multiples to simulate timber of large dimensions.

Advisory Work in Entomology

Much information is still being sought on the identification and control of various types of damage by wood-boring insects in home-grown and imported timber. A problem which has become of increasing importance to users of softwood, in particular for packing cases for goods exported to Australia, is the presence of damage by Siricid wood wasps in such materials. The intensified quarantine measures imposed by the Australian authorities require freedom from this type of insect attack in all softwoods reaching Australia. The Laboratory has been approached by the industries concerned in the United Kingdom for advice on recognition of Siricid damage and for information on sterilization treatments.

Other types of insect damage sometimes associated with infestation by *Sirex* in softwoods from central Europe include infestation by the beetle *Serropalpus barbatus*, the tunnels of which are indistinguishable from those of Siricid wood wasps. An account of this insect and its distribution has been prepared.*

As in previous years, it has again not been possible to meet all the demands for inspections of outside property. Ten such inspections have, however, been carried out.

In addition to enquiries by telephone or personal visit 1167 were dealt with by correspondence during the year.

* Bletchley, J. D. A Little Known Borer in Imported Softwood, *Serropalpus barbatus* Schall. (Coleoptera, Melandryidae). Review of Literature and Recent Occurrences in Great Britain. *Forestry*, 1955, **28** (1), 67-72.

CHEMISTRY

Wood Polysaccharides

The studies on wood hemicelluloses undertaken in co-operation with Professor E. L. Hirst at the University of Edinburgh have been continued. It is proposed that a complete re-investigation of the hemicelluloses of oak wood be carried out. The first studies on these materials were made by O'Dwyer of this Laboratory, who investigated both sapwood and heartwood hemicelluloses. The objects of the present investigations were to prepare as pure samples as possible and to investigate the products, using the techniques of methylation, paper chromatography, etc., in order to gain further insight into the molecular structures of these highly important wood constituents.

Oak heartwood Hemicellulose.—Sawdust prepared from the heartwood of English oak was extracted with alcohol-benzene and the bulk of the tannin was then removed by treatment with 0·1 N sodium hydroxide. The hemicellulose was extracted from the residue with 1·0 N alkali at room temperature. The product was precipitated by the addition of Fehling's solution, the copper complex decomposed with hydrochloric acid and the hemicellulose purified by dissolution and reprecipitation as above. The final product, obtained in a yield of about 5 per cent of the original wood weight, was a white powder which gave on hydrolysis xylose (88 per cent.) and uronic acid.

Oak sapwood Hemicellulose.—In earlier work at this Laboratory O'Dwyer and Campbell* obtained preparations from oak sapwood which contained uronic acid and which gave blue to purple colourations with iodine. One explanation of this may be that these workers were dealing with a mixture of materials comprising a starch fraction and a hemicellulose fraction. Repeated attempts have now been made to isolate a hemicellulose from oak sapwood which does not give a colouration with iodine, but without success. The product finally isolated in bulk was prepared as follows : After exhaustive extraction with boiling water to remove as much as possible of the starch present the residual sawdust was treated with 0·1 N alkali. The hemicellulose was then extracted with 1·0 N sodium hydroxide and was purified as with the heartwood preparation. The product (yield about 5 per cent.) gave a blue colour with iodine and yielded glucose, xylose and uronic acid on hydrolysis.

These two hemicellulose preparations have been sent to Edinburgh for structural investigations. Investigations are also in progress at the Laboratory on the hemicelluloses B and C previously prepared† from beech wood after delignification with sodium chlorite. Hemicellulose B has been methylated and the product fractionated.

Fructose-containing Oligosaccharides from Scots Pine.—Wood from a freshly-felled Scots pine about 15 years old and cut in early spring, 1954, was converted into sawdust. The free sugars were extracted from this material in the usual manner and examined on the paper chromatogram. As well as sucrose, glucose, fructose and small amounts of xylose, a range of oligosaccharides of lower R_G values was detected. Each of these substances gave the characteristic ketose colour with acid naphtharesorcinol on the chromatogram, and, presumably, contained fructose. By examining sections taken from the tree at various heights

* " Report of the Forest Products Research Board, with the Report of the Director of Forest Products Research, for the Year 1935 "—p. 47.

† Forest Products Research 1953 (p. 42). London, H.M.S.O.

it was ascertained that these materials were present in the wood from the pith to the outside of the tree for the whole length of the trunk. Similar materials have previously been found in other plants, such as Jerusalem artichoke and grasses, though their presence in wood does not appear to have been detected hitherto. A detailed investigation of these oligosaccharides, which almost certainly arise from sucrose by enzymic transfructosylation, will be undertaken.

Morabukea Saponins

Investigations on the structure of the saponin present in the heartwood of morabukea have been described previously.* The general nature of the product has been determined and a paper has been published describing the results†.

Further investigation has shown, however, that the products obtained from different trees may differ in constitution. Individual samples of saponin were isolated from the wood of different logs, each of which had been positively identified as morabukea. On hydrolysis of these materials it was found that in some cases only small amounts of galactose were produced, while other samples yielded relatively large amounts. A large sample of saponin of low galactose content was prepared and a detailed examination of this product has been undertaken. From the results obtained so far, it appears that this material has a similar structure to that previously examined. Thus, while the galactose content is here very much lower, methylation experiments have shown that the galactose residues have similar linkages in both products. In both cases, also, a large proportion of glucose " end-groups " is present, as well as some xylose units linked through positions C_1, C_2 and C_4 and some joined through C_1, C_3 and C_4. Full information on the methylation results is not available as yet.

In order to gain further insight into the fine-structure of the saponin molecules the periodate-oxidized material was heated with phenylhydrazine (Barry degradation) and the product methylated. It is hoped that examination of this methylated fragment will provide information on the arrangement of the constituent sugar residues within the molecule.

An attempt is also being made to fractionate the saponin acetate of low galactose content on a column of magnesium silicate.

Arrangements have been made to obtain specimens of morabukea taken from a number of different logs in order to study further the distribution of the saponin within the tree and the composition of saponins from different sources. It would be of interest to know, for example, whether the occurrence of saponins of low galactose content is restricted to certain trees.

Dihydroquercetin from Douglas Fir Bark

In response to a request from Dr. R. J. Boscott, of the University of Birmingham, a small quantity of dihydroquercetin was prepared by extraction of Douglas fir bark. This substance has been isolated by E. F. Kurth from the bark of trees grown in North America in yields of 4·0-9·8 per cent, but its preparation from the bark of the much younger home-grown Douglas fir has not previously been undertaken. The bark was extracted with benzene to remove waxy material, and the residue air-dried and extracted with ether. Evaporation of the ether solution yielded a brown solid, which was extracted with a small volume of hot

* Forest Products Research 1953 (p. 43). London, H.M.S.O.
† LAIDLAW, R. A. Wood Saponins. Part I. *J. Chem. Soc.*, 1954, 752-757.

water. The extract was decolourized with charcoal and filtered hot. On cooling crystals of dihydroquercetin separated and were purified by repeated recrystallization from water. Yield 1 ·4 per cent, m.p. 237° C.

Dihydroquercetin is a colourless crystalline substance which possesses pharmacological properties and is an effective anti-oxidant for prevention of rancidity in fats and oils.

Wood Extractives

Crystalline Substance from Red Meranti.—This material, isolated from the alcoholic extract of the wood after removal of ligneous material, crystallizes from ethyl acetate (m.p. 224° C) or from water. In the latter case it contains water of crystallization which is lost at 150° C and the unhydrated substance again melts at 224° C. Elementary analysis gives C 51 ·08 per cent, H 4 ·85 per cent and the molecular weight (determined at the Chemical Research Laboratory by osmotic pressure measurement) is 363 ·8 (mean of two determinations, 369 ·2 and 358 ·3). These data indicate a possible formula of $C_{15}H_{18}O_{10}$. The ultra-violet absorption spectrum has maxima at 214 m μ (log ε 4 ·5) and 272 m μ (log ε 3 ·96) and an inflexion at 307 m μ (log ε 3 ·53), supporting the aromatic nature of the compound. The substance (8 ·83 per cent OMe) contains one methoxyl group and no acetyl groups. Its phenolic character is indicated by a green colouration with ferric chloride in alcohol, its solubility in sodium hydroxide and sodium carbonate and insolubility in sodium bicarbonate. Acetylation with acetic anhydride in pyridine in a nitrogen atmosphere at room temperature yields an acetate, m.p. 206° C, having 47 ·7 per cent acetyl and 5 ·42 per cent OMe, which is apparently an octa-acetate. Attempts to prepare a crystalline methylation product have so far been unsuccessful.

A 2 : 4-dinitrophenylhydrazone has been prepared, crystallizing from aqueous alcohol in long red needles. When this hydrazone was chromatographed on alumina the first fraction collected crystallized from aqueous alcohol in yellow needles, m.p. 77-83° C, containing 19 ·1 per cent N, and may perhaps be the tri-dinitrophenylhydrazone of a compound of molecular weight 340 formed as a result of the reducing properties of the polyhydroxy-phenol.

Coloured Components of Indian Rosewood and Purpleheart.—A preliminary examination has been made of the colour changes occurring in these timbers on exposure to air and light. Rosewood, when freshly sawn, has a deep red or purple colour which gradually fades to brown on exposure, while purpleheart has initially a light brown colour, which rapidly changes to bright purple and then more slowly to a dull brown. The latter timber is known to contain a leuco-anthocyanin*.

The extracts of rosewood in organic solvents are highly coloured, and substantial amounts of material are dissolved, as the following figures show :—

Percentage extracted with ether	21 ·4.
Percentage extracted with chloroform ..	23 ·4.
Percentage extracted with alcohol ..	31 ·7.

The extractives are not appreciably volatile in steam.

* Robinson, G. M. & Robinson, R. A Survey of Anthocyanins. Part III. Notes on the Distribution of Leuco-anthocyanin. *Biochem. J.*, 1933, 27, 206-212.

Samples of the two woods were placed under different sources of light in air and in nitrogen to find the causes of the colour changes.

Table 4 summarizes the results :—

TABLE IV

Colour Changes in Indian Rosewood and Purpleheart on Exposure to Light

	Rosewood		Purpleheart	
	Nitrogen	Air	Nitrogen	Air
Daylight ..	Faded and started to turn brown after 7 days.	Dark streaks faded and wood turned brown after 7 days.	Pink colour apparent after 1 day: became purple after 10 days.	Pink colour apparent after 1 day: deeper purple after 10 days.
Infra-red 2 hours.	Darkened.	Darkened.	Bright pink-purple.	Bright pink-purple.
Ultra-violet 2 hours.	—	No change.	—	Slightly purple.
Light excluded.	No change after 7 days.	Slight fading of dark streaks: lighter streaks turned brown after 10 days.	No change.	No change.

A considerable rise in temperature occurred in the samples exposed to infra-red radiation and may have accelerated the colour changes.

It appears that the nature of the light to which the wood is exposed is of greater significance than the presence or absence of oxygen.

Production of Fibreboard from Secondary Colonial Timbers

Malayan Timbers.—Satisfactory hardboards have been made on a laboratory scale from each of four timber species submitted for test by the Timber Research Laboratory, Malaya, viz., kempas, red meranti, keruing and balau. In each case the wood chips were first softened by cooking for 30 minutes at temperatures of 170-180° C in solutions of sodium sulphite (3·5 per cent of the weight of wood), containing sufficient sodium bicarbonate (2·5-5·0 per cent of the weight of wood according to the species) to prevent the liquors from becoming appreciably acidic during cooking. The softened chips were then defibred in the disc mill and the resulting pulps screened to remove shives, etc. The highest yields of good quality, fast-running pulp were obtained by means of a single passage through the mill fitted with coarse plates, the shives separating on the screen plate being returned to the mill with succeeding batches of chips. Measurements of power consumption made during defibration gave results which compare favourably with data published by other workers using softwoods. The pulps were formed into sheets and pressed at 185° C and 1000-Lb/sq. in. to form hardboards of $\frac{1}{8}$-in. thickness. In order to produce boards having the highest density and strength the pressure was raised rapidly to its maximum value without any " breathing " periods. The optimal rate of closure which can be employed without introducing " water burns " or other surface blemishes depends on the

species of wood, the best results being obtained with kempas and meranti when a gauge pressure of 1000-Lb/sq. in. was reached in 25 seconds, with keruing in 17 seconds and with balau in 5 seconds.

The boards were tested for density, modulus of rupture and water resistance, as laid down in British Standard 1142 : 1953 " Fibre Building Boards ", the most marked difference between the four species being found in the water resistance of the boards. In the case of kempas, boards made by the simple defibration and pressing technique outlined above possessed sufficiently good strength properties to qualify as either standard or super hardboard, but their water absorption during 24 hours' immersion was excessively high. The necessary improvement in water resistance was effected, however, by spraying the boards immediately after pressing with small quantitites of a drying oil, followed by heat tempering for 2 hours in a hot-air chamber at 180° C. Boards meeting all the requirements for standard hardboard and for super hardboard were produced in this way by using, respectively, 2 per cent and 3·5 per cent by weight of oil.

Boards made from meranti, keruing and balau each had sufficiently low water absorption to qualify as super hardboard when subjected to a heat treatment alone, without addition of oil. In their strength properties the boards from meranti and balau were equivalent to super hardboard, while those from keruing were just below this level, but easily qualified as standard hardboard. In the matter of appearance the boards made from kempas, meranti and keruing were all satisfactory, while those from balau tended to be uneven in colour.

Although this defect could be minimized by very rapid initial pressing, the optimum conditions were difficult to control. In addition, certain difficulties encountered in the defibration of balau chips rendered this species the least suitable of the four tested for board-making.

Sawmill waste, which might provide the raw material for board-making in certain areas of Malaya, has been estimated to contain, approximately, 55 per cent meranti (*Shorea* spp.), 20 per cent keruing, 5 per cent kempas, 5 per cent balau and 15 per cent of various mixed species. A mixture of chips of the four timbers under investigation was made up in, approximately, the same proportions (64 per cent meranti, 24 per cent keruing, 6 per cent kempas, 6 per cent balau) and treated by a process essentially similar to that described above for the separate species. The resulting boards had good appearance and properties and retained the best characteristics of those made from the individual species. The requirements for super hardboard were met in all respects by heat-tempered boards, without any sizing or addition of oil. Thus, although further confirmation is required, there are indications that the production of boards from mixed hardwood species does not present any additional problems and may even have advantages in the quality of the product. This is a matter of some importance in view of the heterogenous nature of tropical forests.

African Pencil Cedar.—The board-making qualities of this timber have been investigated with the object of finding an outlet for the large quantities which are available, which are unsuitable for normal utilization, either as structural or cabinet-making wood or as slats for pencil manufacture. The possibility of combining hardboard manufacture with the extraction of cedarwood oil has also been considered.

The timber supplied for this investigation consisted of (1) old heartwood logs which appeared to be the remains of a mature tree from which the bark and

sapwood had been removed, probably by fungal decay as it lay in the forest, and (2) logs from small, young trees, mainly sapwood. These two materials were examined separately. The old heartwood contained about 5 per cent of oil, determined by extraction with ether or by steam distillation, while extraction with alcohol removed 11·7 per cent by weight, consisting of colouring matter, tannins and other phenolic substances, etc., in addition to the oil. The small logs contained practically no oil and only 1·5 per cent of alcohol-soluble material.

Chips from both the heartwood and the sapwood logs were converted into hardboard by a relatively mild process involving steaming the chips under pressure without chemicals, mechanical defibration in the disc mill, forming the resulting pulp into sheets, and pressing at a high temperature in the usual way. Boards from both these materials had adequate strength to meet the specification for standard hardboard, while those from the heartwood log also possessed excellent water resistance. Those from the small, mainly sapwood, log had much higher water absorption, which could be reduced to the standard hardboard level by heat tempering or to the super hardboard level by oil treatment.

Boards were also made from chips which had been previously extracted with ether or with alcohol in order to examine the effect on the boards of removal of oil and other extractives from the heartwood. It was found that boards made from ether-extracted heartwood, from which most of the oil had been removed, still retained good water-resistant properties, while those made from wood which had been extracted with alcohol, which removed less oil but also extracted other wood components, had lost their water resistance and resembled sapwood boards. Thus, good water resistance does not appear to depend primarily upon the presence of oil in the wood.

Samples of all the boards were also exposed to attack by four wood-destroying fungi for a period of three months under controlled conditions, according to B.S. 1982: 1953. The well known decay-resistant properties of pencil cedar heartwood were retained in the boards made from unextracted heartwood and also in those from ether-extracted heartwood, from which most of the oil had been removed. None of these boards suffered any loss in weight during the period of exposure to fungi. Boards made from sapwood and from alcohol-extracted heartwood, however, were heavily attacked by fungi, losing up to 25 per cent of their initial weight.

Other samples were exposed to attack by termites under controlled conditions at the laboratories of the Commonwealth Scientific and Industrial Research Organization Division of Entomology, Canberra. Boards made from the unextracted heartwood proved to be almost as resistant to attack by termites of the species *Coptotermes lacteus* as the wood itself. The boards from ether-extracted heartwood, while being rather more heavily attacked, were still much superior either to boards made from sapwood or to wood samples from a non-resistant species.

From the above results it is apparent that water resistance, resistance to fungal decay, and resistance to attack by termites are all largely retained both in boards from heartwood and in those from heartwood from which most of the oil has been extracted by ether, indicating that the resistant properties of the boards are associated with wood components other than the oil. It should therefore be possible to recover the oil, which possesses commercial value, by means of solvents or steam distillation, and then to produce hardboard from the residual wood having high qualities of strength and durability under tropical conditions.

Considerable interest is being shown in Malaya and in Kenya in the results of the board-making trials on timbers from these two areas and close contact is being maintained with the interested persons.

Advisory Work in Chemistry

The number of enquiries dealt with by letter during the year was 194. In addition, visitors to the Laboratory called on 42 occasions to discuss specific problems. Most prominent among the enquiries are questions concerning stains on timber and their removal, selection of timber for construction of vats and other equipment in which the wood is in contact with chemicals, corrosion of metals in association with wood, and production of fibreboard. Enquiries are also received in smaller numbers on a wide range of other topics and provide a useful guide to the types of problem encountered in the wood-using industries.

PHYSICS

Elastic Properties of Wood and Plywood

Further experiments have been carried out to measure the effect of shear deflection on the frequency of bending vibration of wooden beams. The results confirm the conclusion, drawn in last year's Report (p. 48), that although it is possible to account for the observed frequencies in terms of the shear effect, at the same time, the method does not provide a satisfactory way of measuring shear modulus.

Work done some years ago on the frequency of vibration and deflection under load of plywood plates has been re-examined. It has proved possible to obtain improved equations expressing these quantities in terms of the elastic constants and dimensions of the plywood. A comparison has been made between the values predicted by these formulae and those measured experimentally. The comparison shows that there is still some discrepancy between the experimental and theoretical values. This, however, is probably due to the difficulty of realizing experimentally at the edges of the plates the exact conditions which have to be assumed in deriving the theoretical results.

Moisture Movement and Distribution in Wood

In connexion with work being carried out in seasoning (see page 11), experiments were set up to find the time required for equilibrium to be established when one surface of a wood disc is in contact with free water and the other surface is exposed to dry air. The discs were of Douglas fir, and ranged from $\frac{1}{4}$-in. to $1\frac{1}{2}$-in. in thickness. The " Perspex " vessels holding the discs were placed in a dish containing P_2O_5 to give the low humidity on one face of the wood. The water vapour passing through the disc is absorbed by the P_2O_5, so that by weighing periodically the assembly consisting of " Perspex " vessel and wood disc, the rate of movement of water can be determined.

It was assumed that a state of equilibrium existed within the wood when this rate became constant. The time required for the establishment of a steady rate of flow varied from a few days for the thinner samples to some weeks for the thicker samples.

After two months, samples of each size were taken off and sawn into sections, as far as was possible, for the determination of the moisture content distribution

in the disc. Owing to the impracticability of sawing a sufficient number of sections from the $\frac{1}{4}$-in. and $\frac{1}{2}$-in. thick discs moisture distribution curves were obtained for the 1-in. and $1\frac{1}{2}$-in. samples only.

Corresponding curves obtained for discs taken off five weeks later showed good agreement, thus confirming that equilibrium within the wood had been established when the rate of moisture movement through the disc became constant.

There are a number of disadvantages associated with the use of a saw for cutting sections in moisture distribution studies. One of them, namely, the impossibility of cutting a sufficient number of sections from specimens less than about $\frac{1}{2}$-in. thick, has already been mentioned. This difficulty does not arise with thicker specimens, but here a considerable amount of wood is lost as sawdust, and the appreciable heat developed will undoubtedly alter the moisture content of the sections.

For these reasons a method has been developed in which the sample, tightly clamped, is cut into sections by a blade held in grooves and forced forward to cut the wood by turning a screw. Using this method of cutting a $\frac{1}{2}$-in. thick disc yields as many as seven sections, which can be made sufficiently thin to give additional data at the critical portions of the moisture distribution curve.

This work on moisture gradients is of interest in the use of wood in boats, vats and barrels. The experiments so far carried out have been confined to initially air-dry wood with water on one face and a low humidity atmosphere on the other. They have confirmed the existence of an extremely steep moisture gradient close to the wet face ; for example, in a 1-in. thick specimen, the moisture content at the face in contact with water is about 90 per cent, falling to about 35 per cent at a distance of $\frac{1}{8}$-in. from this face.

Experiments are now in progress under identical conditions, but with the wood initially waterlogged instead of air-dry, in order to find the effect of this change on both the final moisture distribution and the time required to reach equilibrium.

Specific Heat and Heat of Wetting of Wood

Results of measurements on the specific heat of wood as affected by moisture content were discussed in last year's Report (p. 46), when it was pointed out that the values observed experimentally are greater than the values calculated from the specific heats and amounts of wood and water present. More recently, work on this subject has been directed towards testing whether this discrepancy can be accounted for by the fact that when wood is wetted with water, heat is evolved, and that this heat of wetting varies with temperature. It can, in fact, be shown that the difference between the observed and calculated specific heats should equal the rate of change in heat of wetting with temperature. Some time has therefore been devoted to developing a technique and to building a calorimeter for the measurement of heat of wetting of wood in the form of sawdust. During the course of this work a curve connecting heat of wetting with moisture content has been obtained (Fig. 3). This is in reasonable agreement with previous determinations and shows that the initial heat of wetting at 39° C is about 17 cal/g, falling to zero at about 32 per cent moisture content. Measurements have also been made of the variation of the heat of wetting of dry beech sawdust with temperature. The results are rather scattered and it is difficult to derive from

them satisfactory estimates of change in heat of wetting with temperature. Nevertheless, they show that this change is in the right direction and of the correct order of magnitude to account for the discrepancy between the observed and calculated specific heats. Attempts are now being made to improve the accuracy, both of the specific heat and heat of wetting measurements.

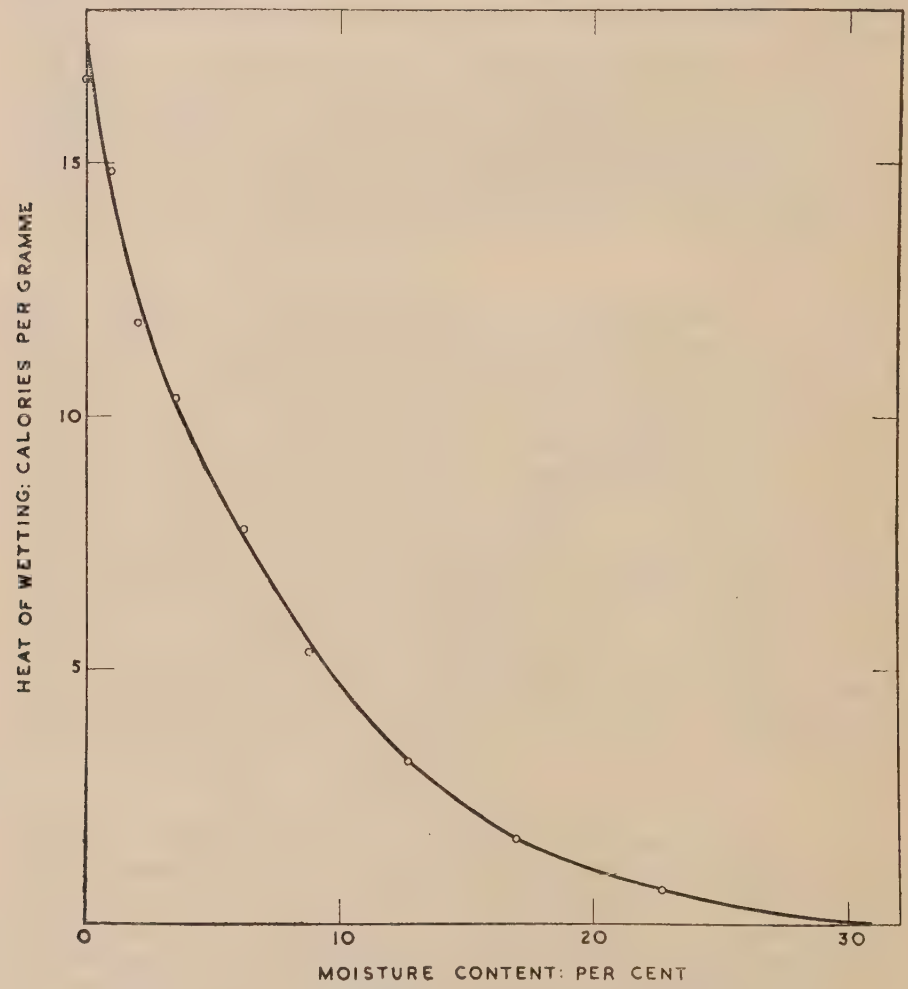


FIG. 3. HEAT OF WETTING OF BEECH SAWDUST AT 39° C

Advisory Work in Physics

Advisory work has dealt with the following topics : ultrasonic detection of flaws in glue joints ; construction of an apparatus for measuring the relation between moisture content and relative humidity of wood ; the friction of wood on concrete ; the use of cane for the reeds of musical instruments ; the thermal conductivity of obeche and slag wool ; the compressibility of cork ; dielectric loss in iroko and abura ; the specific heat of wood ; the detection of metal in timber ; the thermal expansion of corkboard ; the electrical properties of mansonia ; the use of strain gauges on wood ; the " working " of frozen wood, and the effect of moisture content on the electrical conductivity of wood.

EXTERNAL RELATIONS

Timbers for Test

During the year a total of 5111 cu. ft of timber was brought into the Laboratory for test. It comprised 1556 cu. ft (made up of 130 cu. ft softwood and 1426 cu. ft hardwood) from overseas, and 3555 cu. ft (made up of 296 cu. ft. of hardwood and 3259 cu. ft of softwood) from Great Britain. The following is the detailed list of timber procured :—

Name	*Source*	*Quantity* (cu. ft)	
Imported			
French ash	Commercial	32	
Balsa	Commercial	30	
Gaboon	Commercial	75	
Aningueria	Uganda Forest Department	271	
Abura	Uganda Forest Department	152	
Piptadenia buchananii	Uganda Forest Department	255	
Piptadenia africana	Uganda Forest Department	287	
Indian rosewood	Commercial	156	
Andaman bullet wood	Commercial	5	
African mahogany	Commercial	193	
Yellow pine	Commercial	100	
Nicaraguan pitch pine	Commercial	30	
Home-grown			
Oak	Forestry Commission	122	
Beech	Forestry Commission	131	
Nothofagus obliqua	Forestry Commission	12	
London plane	Commercial	31	
Scots pine	Forestry Commission	393	
3 parcels Sitka spruce	Forestry Commission	1320	
Japanese larch pit-props	Forestry Commission	120	pieces
Corsican pine	Forestry Commission	774	
Western hemlock	Forestry Commission	460	
Western red cedar	Forestry Commission	292	

Timber Quality in Relation to Silviculture

The work in co-operation with the Forestry Commission on the quality of timber in relation to site and soil has continued. Last year three parcels were brought in, but this year the work has been increased and six parcels, comprising three parcels of Sitka spruce and one each of Corsican pine, western hemlock and western red cedar, have been dealt with.

Three reports on this work were completed, two on Sitka spruce from Drumtochty Forest, Scotland, and Eggesford Forest, Devon, and a report on Norway spruce from Drummond Hill Forest, Scotland. The report on the Sitka spruce from North Wales is in the press.

The test on the Sitka spruce from Drumtochty Forest, Scotland, showed the timber to be much inferior to the other parcels tested. It was very fast grown,

prone to severe collapse, and weak in strength. The Sitka spruce from Devonshire was satisfactory, being slightly weaker than that from Gravetye but better than any other parcels yet tested.

From the limited tests so far carried out, the tentative conclusion is that Sitka spruce grown in the South of England is stronger than that grown further north and in Scotland.

The Norway spruce from Drummond Hill Forest proved to be satisfactory timber, sawing and working well, and the showing on the limited materials so far tested is that it seems to be much more satisfactory than the Sitka spruce.

The detailed study of the trees has continued and the method for arriving at the results, introduced last year, has worked satisfactorily. This work is lengthy, and to speed it up a ring-by-ring specific gravity is taken only at 10 and 50 ft on the new species being tested, and for the butt and intermediate ten-foot lengths the specific gravity is determined on the whole disc.

Surveys of Main Timber Industries

It has been possible to extend the number and scope of visits to industry. Some 40 visits were made by members of External Relations Section to sawmills, the wood-using industries, research associations and technical exhibitions in England and Scotland. The establishments visited included those of timber importers, merchants and sawmillers, furniture manufacturers, carriage and wagon builders and adhesives manufacturers. The wind-blown areas in Scotland were also visited, and many woodland and logging operations were inspected to gain information on the milling and on the state of the timber.

Revision of Empire Timbers Handbook

The work on the book on hardwoods has now been completed and is ready for the publishers. A companion book which will deal with about 60 species of commercial softwoods has been started, and should be completed within the next 12 months.

Visitors

The Laboratory was honoured by a visit from the Lord President of the Council, Lord Salisbury, who made a tour of the Sections and inspected the work in hand. His Lordship was good enough to express appreciation of what he saw during his visit.

A very heavy general programme of visitors was handled during the year. The number is increasing, especially from members of trades using timber. Firms such as timber merchants, manufacturers of wooden articles, builders, architects, etc., sent 139 representatives during the year, as against 102 in 1953 and 64 in 1952.

The Forestry Commission also sent two parties, and two societies dealing with timber and wood were received. The Colonial Office sent 19 Public Works Department engineers from all parts of the Commonwealth for a day visit.

The number of overseas visitors remains high, there being 84 from 35 different countries and colonies, *viz.* : Australia, British Borneo, British Guiana, Canada, Ceylon, Denmark, Egypt, Fiji, France, Germany, the Gold Coast, Greece, Hong Kong, India, Indonesia, Israel, Japan, Kenya, Malaya, Malta, New

Zealand, Nigeria, Northern Rhodesia, Norway, Pakistan, Persia, Portugal, the Union of South Africa, Sweden, Tanganyika, Trinidad, Turkey, Uganda, the United States, and Yugoslavia.

These visitors represented all classes of the timber industry.

Education

During the year the usual courses for forestry students from the Universities of Oxford (31 students), Edinburgh (23 students), Aberdeen (12 students) and Bangor (12 students) were given. The Oxford post-graduate course included many men from the Forestry Departments of the Commonwealth and Empire. The customary 4-day course for Instructors of the Timber Development Association was held, and the City and Guilds engineering students of the Imperial College made their annual visit of instruction. Special courses in preservation were also provided for railway engineers concerned with the maintenance of the permanent way.

The usual Seasoning courses for kiln operators were held 6 times, with a total of 57 students attending. Five trainees were given courses in wood bending.

The number of students coming from Technical Colleges has again increased, and it has again been necessary to refuse many applications to visit.

Thirteen individual students have been given longer-term instruction for periods ranging from one week to nine months. Four of these were foreign, eight from the Commonwealth and Empire, and one from a Service Department. It is of interest to note that since early 1952 the Laboratory has had, almost continuously, a British Council or an F.A.O. (United Nations) long-term overseas student (Switzerland, Yugoslavia, Thailand, Turkey, India).

By arrangement with the Central Council for the Care of Churches, a two-day course for architects was held at the Laboratory in May, 1954, on the detection and treatment of fungal decay and infestation by wood-boring insects in structural timbers, with special reference to the death-watch beetle.

The course was designed for specialist architects concerned with the repair and maintenance of old churches in connexion with the Historic Churches Preservation Trust.

During the year the customary lectures and broadcasts by specialist officers on the practical application of timber research were given to public and technical audiences. The Dry Rot and Woodworm Exhibition was on show for 6 weeks during the summer at the Royal Sanitary Institute and was visited by several thousand persons.

External Relations.—Advisory Work

Technical enquiries dealt with by letter during the year totalled 195.

F. Y. HENDERSON,
Director.

Forest Products Research Laboratory,
Princes Risborough,
Aylesbury, Bucks.

March, 1955.

APPENDIX I

STAFF AT THE FOREST PRODUCTS RESEARCH LABORATORY

31*st December*, 1954

Director of Forest Products Research : F. Y. Henderson, C.B.E., D.Sc., D.I.C.

ADMINISTRATION

Assistant Director : S. T. C. Stillwell, O.B.E., B.Sc.
Senior Principal Scientific Officers : J. Bryan, M.Eng., A.M.Inst.C.E. ; K. T. St. G. Cartwright, M.A., D.I.C.
Higher Executive Officer : R. D. Weeks, M.B.E.
Executive Officer : Miss D. Lacey.

SECTION OF WOOD STRUCTURE

Principal Scientific Officers : B. J. Rendle, B.Sc., A.R.C.S. (Officer in Charge) ; E. W. J. Phillips, B.Sc., Ph.D., A.R.C.S.
Scientific Officer : J. D. Brazier, B.Sc.
Experimental Officer : G. L. Franklin.
Temporary Assistant Experimental Officer : Miss L. M. Holtham.

SECTION OF PHYSICS

Principal Scientific Officer : R. F. S. Hearmon, F.Inst.P. (Officer in Charge).
Experimental Officers : J. N. Burcham, B.Sc. ; J. McC. Paton.
Assistant Experimental Officer : E. H. Adams.

SECTION OF SEASONING

Principal Scientific Officer : W. C. Stevens, M.A., A.M.I.Mech.E. (Officer in Charge).
Senior Experimental Officers : R. E. Hodge, A.I.Mech.E. ; D. D. Johnston ; G. H. Pratt ; N. Turner.
Experimental Officer : A. R. Dean.
Assistant Experimental Officer : R. H. Wynands.
Temporary Assistant Experimental Officer : T. R. Suckling.

SECTION OF TIMBER MECHANICS

Principal Scientific Officer : F. H. Armstrong, M.Sc., M.I.Mech.E. (Officer in Charge).
Scientific Officer : A. J. Comben, B.Sc.
Senior Experimental Officer : A. J. Foord.
Experimental Officers : W. T. Curry ; J. G. Sunley, M.Sc.
Assistant Experimental Officers : G. R. Brock ; Miss W. M. Fogerty ; W. T. Hide

SECTION OF WOOD PRESERVATION

Principal Scientific Officer : N. A. Richardson, B.Sc., A.R.I.C. (Officer in Charge).
Senior Experimental Officer : D. N. R. Smith.
Experimental Officers : D. F. Purslow, B.Sc. ; L. W. Redding.
Assistant Experimental Officers : R. Cockcroft ; Miss E. Lee.

SECTION OF CHEMISTRY

Principal Scientific Officer : R. H. Farmer, B.A., B.Sc., D.Sc.(Tech.), F.R.I.C. (Officer in Charge).
Senior Scientific Officer : R. A. Laidlaw, B.Sc., Ph.D.
Scientific Officer : Mrs. W. R. Carruthers, B.Sc.
Experimental Officers : D. F. Packman, B.E.M. ; L. C. Pinion, B.Sc.
Assistant Experimental Officer : Mrs. A. Suckling.

SECTION OF MYCOLOGY

Senior Principal Scientific Officer : W. P. K. Findlay, D.Sc., A.R.C.S., D.I.C. A.I.C.T.A. (Officer in Charge).
Senior Scientific Officer : J. G. Savory, B.Sc.
Experimental Officer : E. C. Badcock.
Assistant Experimental Officer : Miss C. A. Clements, B.Sc.

SECTION OF ENTOMOLOGY

Principal Scientific Officers : R. C. Fisher, B.Sc., Ph.D., F.R.S.E. (Officer in Charge).
J. D. Bletchly, B.A., B.Sc., F.R.E.S.
Scientific Officer : M. G. White, M.A., F.R.E.S.
Senior Experimental Officer : E. C. Harris, F.R.E.S.
Assistant Experimental Officer : Miss J. M. Taylor, B.Sc.

SECTION OF WOODWORKING

Principal Scientific Officer : P. Harris, B.Sc.(Eng.), A.M.I.Mech.E. (Officer in Charge).
Senior Experimental Officer : R. Goodchild.
Experimental Officer : H. J. Endersby.

SECTION OF EXTERNAL RELATIONS

Principal Scientific Officer : F. G. O. Pearson, B.Sc. (Officer in Charge).
Senior Experimental Officer : A. V. Thomas, M.Eng.
Experimental Officer : Miss C. Webster.
Assistant Experimental Officer : Miss H. A. Fielding, B.A.

SECTION OF COMPOSITE WOOD

Principal Scientific Officer : R. A. G. Knight, B.Sc.(Eng.), M.I.Mech.E. (Officer in Charge).
Scientific Officer : J. F. S. Carruthers, B.Sc., A.M.I.Mech.E.
Senior Experimental Officers : L. S. Doman ; R. J. Newall.
Experimental Officer : R. W. Hudson.

SECTION OF PUBLICATIONS AND RECORDS

Senior Experimental Officer : C. J. N. McCracken, B.A., Dip. For. (Officer in Charge).
Experimental Officer : C. L. Stocker, B.A., Dip.For.
Assistant Experimental Officer : Miss E. M. MacGregor Wood.

DRAWING OFFICE AND PHOTOGRAPHY

Senior Photographer : W. J. Baldwin.
Experimental Officer : E. A. Steel, A.I.Mech.E.

APPENDIX II

LIST OF PUBLICATIONS ISSUED DURING 1954

A. Stationery Office Publications

Forest Products Research 1953

BULLETINS

No. 30. Mechanics of Sawing : Band and Circular Saws. By P. Harris, B.Sc. (Eng.), A.M.I.Mech.E.

No. 31. Prevention of Decay of Wood in Boats. By J. G. Savory, B.Sc., and D. F. Packman.

No. 32. Field Tests on Wood Preservatives Used for Pressure Treatment. By D. N. Smith.

No. 33. The Strength Properties of Plywood. Part II. The Effect of the Geometry of Construction. By W. T. Curry.

SPECIAL REPORT

No. 8. The Dielectric Properties of Wood. By R. F. S. Hearmon, F.Inst.P., and J. N. Burcham, B.Sc.

B. Other Publications

LEAFLETS*

No. 6. Dry Rot in Wood. Recognition, Prevention and Cure. (*Revised edition.*)

No. 45. The Steam Bending Properties of Various Timbers. (*Revised edition.*)

No. 47. The Movement of Timbers.

No. 48. Hardwoods for Industrial Flooring.

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* Obtainable gratis from the Laboratory (Princes Risborough, Aylesbury, Bucks.).

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Hearmon, R. F. S. *Wood.* (Being Chapter V of *Building Materials : their Elasticity and Inelasticity.* Ed. by M. Reiner. Amsterdam, North Holland Publishing Co.)

Hearmon, R. F. S. & Sekhar, A. C. The Frequency of Vibration and the Deflection under Concentrated Load of Rectangular Plates. *Comp. Wood*, 1954, **1** (4), 77-88.

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APPENDIX III

REFERENCE LIST OF COMMON NAMES CITED IN TEXT

Abura=*Mitragyna ciliata.*
Adwea=*Pachylobus barteri.*
Afara (white afara)=*Terminalia superba.*
Agba=*Gossweilerodendron balsamiferum.*
Aningueria=*Aningueria altissima.*
Apple=*Malus sylvestris* (*Malus pumila, Pyrus malus*).
Ash, English=*Fraxinus excelsior.*
Ash, French=*Fraxinus excelsior.*
Balau=*Shorea* spp.
Balsa=*Ochroma lagopus.*
Banga wanga=*Amblygonocarpus obtusangulus.*
Beech=*Fagus sylvatica.*
Boxwood, Maracaibo=*Gossypiospermum praecox.*
Bullet-wood, Andaman=*Mimusops littoralis.*

Canarium, African=*Canarium schweinfurthii.*
Cedar, African pencil=*Juniperus procera.*
Cedar, Western red=*Thuja plicata.*
Cherry=*Prunus avium.*
Chestnut, Sweet=*Castanea sativa.*

Dahoma=*Piptadenia africana.*

Elm=*Ulmus* spp.

Fir, Douglas=*Pseudotsuga taxifolia.*

Gaboon=*Aucoumea klaineana.*

Haldu=*Adina cordifolia.*
Hemlock, Western=*Tsuga heterophylla.*
Hickory=*Carya* spp.
Hornbeam=*Carpinus betulus.*

Idigbo=*Terminalia ivorensis.*
Iroko=*Chlorophora excelsa.*

Kempas=*Koompassia malaccensis.*
Keruing=*Dipterocarpus* spp.
Kwao=*Adina cordifolia.*

Larch, Japanese=*Larix leptolepis.*

Mahogany, African=*Khaya* spp.
Mansonia=*Mansonia altissima.*
Maple, Field=*Acer campestre.*
Meranti=*Shorea* spp.

Meranti, Red=*Shorea* spp.
Morabukea=*Mora gonggrijpii.*
Muchenche=*Piptadenia buchananii.*

Nkunya=*Manilkara cuneifolia.*

Oak=*Quercus* spp.
Oak, European=*Quercus robur* and *Q. petraea.*
Oak, Lucombe=*Quercus lucombeana* (a hybrid oak).
Oak, Turkey=*Quercus cerris.*
Obeche=*Triplochiton scleroxylon.*
Okwen=*Brachystegia* spp.

Pine, Corsican=*Pinus nigra* var. *calabrica* (*P. laricio*).
Pine, Nicaraguan pitch=principally *Pinus caribaea.*
Pine, Scots=*Pinus sylvestris.*
Pine, Yellow=*Pinus strobus.*
Plane, London=*Platanus acerifolia.*
Podo=*Podocarpus* spp.
Poplar=*Populus* spp.
Purpleheart=*Peltogyne* spp.

Ramin=*Gonystylus* spp.
Redwood=*Pinus sylvestris.*
Rosewood, Indian=*Dalbergia latifolia.*

Sapele=*Entandrophragma cylindricum.*
Sepetir=*Pseudosindora palustris.*
Serrette=*Byrsonima spicata.*
Service tree=*Sorbus torminalis.*
Spruce, Norway=*Picea abies.*
Spruce, Sitka=*Picea sitchensis.*
Sterculia, Brown=*Sterculia rhinopetala.*

Teak=*Tectona grandis.*

Utile=*Entandrophragma utile.*

Wallaba=*Eperua falcata, E. grandiflora.*
Wellintonia=*Sequoia wellingtonia.*
Willow, Cricket bat=*Salix coerulea.*

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